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Tug Fleet and Ground Operations Schedules and Controls

MARTIN MARIETTA

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TUG FLEET AND GROUND OPERATIONS SCHEDULES AND CONTROLS

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FOREWORD

This final report, submitted in accordance with Data Procurement Document number 480 dated June 1974, contract NAS8-31011, is published in three volumes:

Volume I - Executive Summary (DRL MA-04)

Volume II - Part I Final Report (DRL MA-03)

Part II Addenda (DRL MA-03)

Part III Appendixes (DRL MA-03)

Volume III - Program Study Cost Estimates (DRL MF003M)

The content of each volume is shown in the diagram on the following page.

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TUG FLEET AND GROUND OPERATIONS SCHEDULES AND CONTROLS, FINAL REPORT (NAS8-31011)

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GLOSSARY

A&E	Architectural and Engineering
APS	Auxiliary Propulsion System
C&W	Caution and Warning
CCB	Configuration Control Board
CCMS	Command Control Monitoring System
CDS	Central Data System
CKAFS	Cape Kennedy Air Force Station
COR	Contracting Office Representative
CST	Combined Systems Test
CTMCF	Common Tug Maintenance and Checkout Facility
DA	Double Amplitude
DOD	Department of Defense
EMC/EMI	Electromagnetic Compatibility/Interference
ETR	Eastern Test Range
F/C	Fuel Cell
FCR	Facilities Change Request
FECP	Facilities Engineering Change Proposal
FIT	Functional Interface Test
FMEA	Failure Modes and Effect Analysis
FWG	Facility Working Group
GSE	Ground Support Equipment
HIM	Hardware Interface Module
H.P.	High Pressure
I/F	Interface

I/O	Input/Output
IOC	Initial Operational Capability
IUS	Interim Upper Stage
JSC	Johnson Space Center
KPF	Kick Stage Processing Facility
KSC	Kennedy Space Center
LCC	Launch Control Center
L.P.	Low Pressure
LPS	Launch Processing System
LRU	Line Replaceable Unit
MDF	Mate-Demate Fixture
MIC	Management Information Center
MPS	Main Propulsion System
MSFC	Marshall Space Flight Center
MSI	Maintainability Significant Item
MSS/PSS	Mission Specialist Station/Payload Specialist Station
MTBF	Mean Time between Failure
MTBR	Mean Time between Repair
NASA	National Aeronautics Space Administration
NN/D	Non-NASA/DOD
O&M	Operation and Maintenance
OFI	Operational Flight Instrumentation
OIS	Operational Intercommunication System
OLF	Orbiter Landing Field
OMD	Operations Maintenance Documentation

OMI	Operational Maintenance Instruction
OPF	Orbiter Processing Facility
PCR	Payload Changeout Room
P/L	Payload
PMF	Payload Mate Facility
PPR	Payload Processing Room
RFP	Request for Proposal
RMS	Remote Manipulator System
RTG	Radioisotopic Thermal Generator
S&E	Science and Engineering
SAWG	Site Activation Working Group
S/C	Spacecraft
SCF	Satellite (Spacecraft) Control Facility
SGLS	Space Ground Link System
SHE	System Health Evaluation
SPF	Spacecraft Processing Facility
SSPD	Space Shuttle Payload Description
SRT	Supporting Research and Technology
STDN	Space Tracking and Data Network
STS	Space Transportation System
TBD	To be determined
TFP	Tug Processing Facility
TSE	Transportation Support Equipment
VAB	Vertical Assembly Building
VSWR	Voltage Standing Wave Ratio
WBS	Work Breakdown Structure

I. INTRODUCTION

The Space Shuttle is being designed to provide economical transportation to and from low Earth orbit. The mission model, however, also identifies missions to higher energy orbits and/or to the planets. In order to accomplish these high energy missions, additional propulsive stages are required.

The propulsive stages for performance of the high energy missions fall into three categories: the Interim-Upper-Stage (IUS), the Space Tug, and their associated kick stages. The IUS will be developed first, by DOD, with an operational date compatible with the operational date of Space Shuttle. The Tug will be developed by NASA for use during the 1983 to 1991 time frame. A transition period of at least one year is anticipated whereby both IUS and Tug will be used for accomplishment of high energy missions.

This Tug Fleet and Ground Operations Schedules and Controls Study addresses both ground operational data and technical requirements that span the Tug planning phase and operations phase. A similar study covering mission operations (by others) provides the complimentary flight operations details. The two studies provide the planning data requirements, resource allocation, and control milestones for supporting the requirements of the STS program.

This Tug Fleet and Ground Operations Schedules and Controls Study incorporates the basic ground operations requirements and concepts provided by previous studies with the interrelationships of the planning, IUS transition, and Tug fleet operations phases. The interrelationships of these phases were studied as a system to optimize overall program benefits and minimize operational risk factors.

A. GOALS AND OBJECTIVES

In many previous aerospace programs, the operations phase requirements have been considered too late to affect design and development (acquisition phase). This has not always resulted in the most efficient operation and effective cost operations, but rather one that accommodates fixed designs and hardware configurations. While this has been acceptable on past programs having limited operational phases (one of a kind, one or two flights) where DDT&E costs far overshadowed operational costs, it will not be acceptable for Shuttle elements such as the Tug with an extended operational phase. The objectives of this study may then be defined as follows:

1) Provide operations phase data to support the Shuttle PDR;

2) Provide early operations phase inputs to Tug design and development;

3) Develop ground operations planning inputs for use on concurrent and subsequent studies;

4) Optimize ground operations requirements and processing based on current Tug baseline;

5) Provide planning for fleet utilization and management.

NASA recognized this concern early in the Shuttle era. Consequently, two of the objectives of this study are to provide early operations phase inputs into hardware designs and interfaces. Operations phase inputs such as access for maintenance, checkout, and servicing, and postmission safing considerations have been analyzed and inputs made available to support Shuttle PDR and to influence early Tug design and development.

In addition, the study developed and optimized ground operations planning based on present Tug baseline definition. This planning data supported the current series of contractor studies and subsequent NASA and contractor studies.

Finally, an objective of this study was to develop preliminary planning for management methods, such as fleet utilization scheduling techniques, and performance measurement systems that would support and implement the ground operations planning.

B. GROUND RULES/ASSUMPTIONS AND GUIDELINES

The ground operations requirements developed in this study are based on specific ground rules and assumptions. The notation after the ground rule/assumptions shows the source.

These ground rules/assumptions were applied as applicable to the operations analysis in developing the flows, resource requirements, and maintenance requirements:

1) The spacecraft is assumed to be flight ready when it is received for Tug/spacecraft integration (Ref VI-4).

2) Tug ground operations times are presented in working hours based on 5-day work week, with two shifts per day at KSC and one shift per day at WTR (Ref VI-4).

3) Times for Tug activity at the launch site that involve the Orbiter are governed by the Space Shuttle turnaround allocation of June 21, 1974 (Study COR direction).

4) Baseline Tug flows are based on a single cycle operational Tug sequence. Contingency planning is not incorporated. The influence of mission model and traffic is not incorporated (Ref VI-4).

5) Nominal Tug/Orbiter recovery is at the launch site (Ref VI-4).

6) No maintenance of the Tug will be performed while in the Orbiter cargo bay (Ref VI-4).

7) IUS propellant tanks will always be empty on return to Earth (Study team assumptions).

8) A normal mission will purge IUS tanks before IUS-Orbiter dock (Study team assumptions).

9) Aborted Tug safing will be done on the runway (Ref VI-1).

10) For purpose of this study, the mission duration will be six days, launch to landing (Ref VI-4).

11) LPS will be used to the maximum extent possible (Study team assumptions).

12) While installed in the cargo bay, communications to the spacecraft will be through the Tug (Study COR direction).

13) For study purposes, the Tug can be transported in the horizontal position with or without APS propellants (Study team assumptions).

14) All IUS operations will be at ETR (Study COR Direction).

15) IUS will be operational 1980 through 1984 (Ground rules in study Statement of Work).

16) Space Tug will be operational in 1983 (December) (Ground rules in study Statement of Work).

17) DOD and NASA Tugs will be identical and interchangeable (Ground rules in study Statement of Work).

18) No LPS DDT&E costs will be chargeable to Tug. IUS/Tug dedicated LPS hardware is chargeable (Ground rules in study Statement of Work).

19) Space Tug configuration is based on "Baseline Space Tug Configuration Definition", MSFC 68M00039-2.

20) Tug propellant tanks will be dumped and purged before return to Earth. Residuals will be left in the He spheres to repressurize tanks on entry. (Study team assumptions and agreement with cognizant contractor on current series of studies).

21) Critical co-alignment of guidance components is accomplished off-Tug on a plate that is mechanically aligned to the Tug structure (Study team assumptions).

C. STUDY PLAN

1.0 Study Approach

This study consisted of a series of twelve tasks (Fig. I-1), that developed a baseline Space Tug processing flow, resource requirements, analyzed the impact of the operational requirements on other program phases, and documented the results in an overall Ground Operations Schedule and Control Plan, as part of the final report.

Task 1.0 defined the Tug processing requirements for a green light single-cycle flow. Special emphasis assessments in Task 2.0 were used to complement the Task 1.0 effort and expand the level of detail in specific interest areas. Special emphasis assessments are included in Vol II Addenda.

Tasks 3.0 through 6.0 operated on the Task 1.0 baseline to develop requirements for other program phases. In Task 3.0, the impact of the traffic was considered to establish the Tug fleet size. Contingency analysis was employed to realistically size the fleet under other than nominal conditions, and fleet management techniques were defined. Task 5.0 defined the site activation. requirements for the Space Tug based on the operational data developed in Task 1.0. After activation requirements were understood, the transition from IUS to Tug was analyzed in Task 6.0, giving special consideration to the period of time when concurrent IUS and Tug operations may be required. Task 4.0 determined the requirements for Tug to spacecraft (payload) integration in the mission planning era.

In Task 7.0, results of Task 1.0 through 6.0 were analyzed to determine the affect on Tug design and development (acquisition phase). Each task that resulted in a subplan was integrated in Task 8.0 into an overall plan. The subplan elements were subjected to a sensitivity analysis in Task 9.0 before finalization. The final subplans are given in Chapter III of this report.

Finally, in Task 10 through 12, a study was performed to assess the effect of an alternative processing flow in an unclean environment, to identify any SRT requirements, and to define recommended additional efforts.

2.0 Summary of Statement of Work Tasks

Task 1.0, Analyze Space Tug Operational Phase - In this task, the operational period for the baseline Tug was analyzed. A functional flow diagram for Tug launch site activities, beginning with initial arrival at the launch site and/or Shuttle landing through safing, payload demating, refurbishment, maintenance and checkout, payload mating, Shuttle mating, and launch countdown through liftoff was developed. Preliminary manpower, facility,

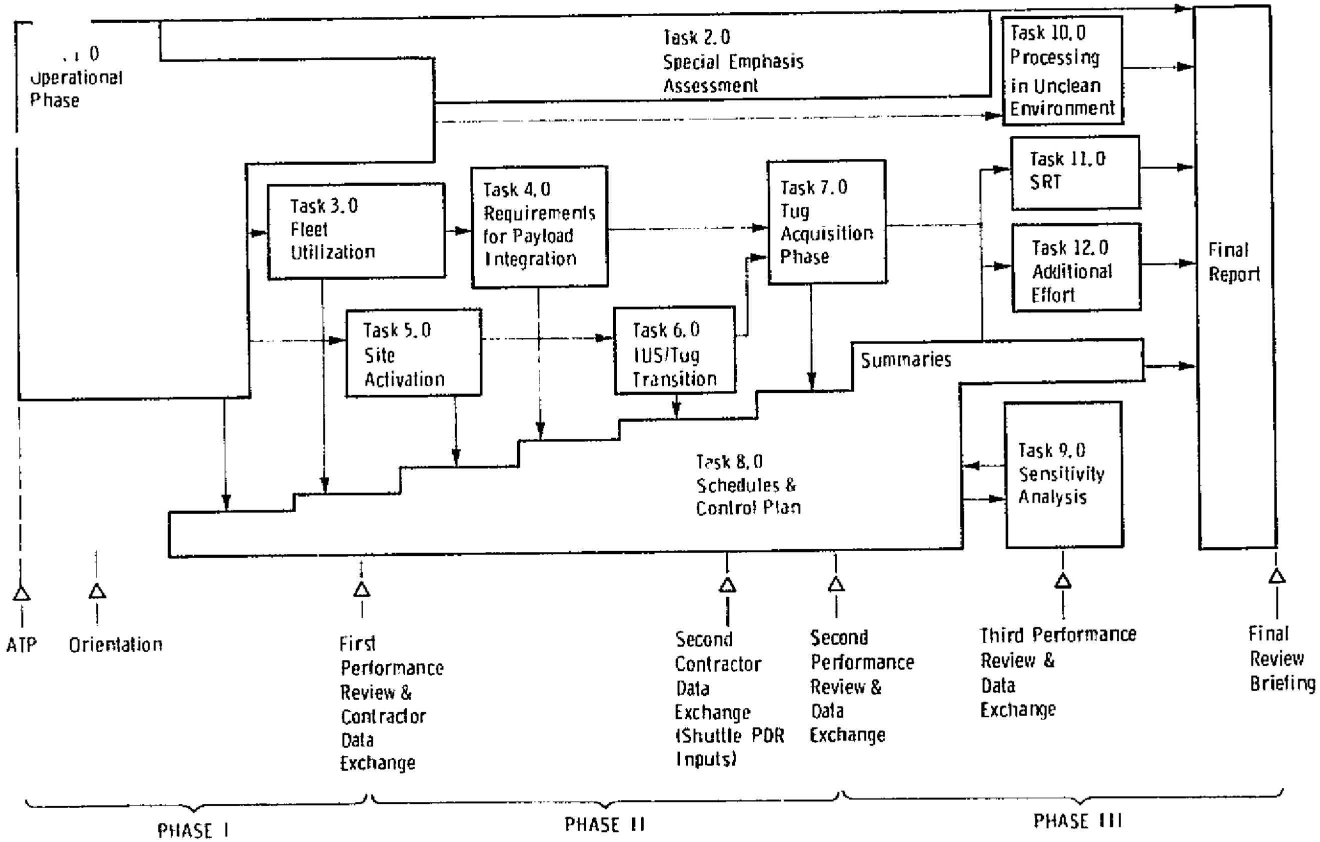

Figure I-1 Study Flow Summary

GSE, and maintenance requirements necessary to support this functional flow sequence were identified. Software requirements and delta WTR requirements were identified. This baseline data was used to develop estimated costs per flight, and documented in accordance with the approved WBS. Data produced in this task is presented in Subplan A for the Tug operational phase and in Appendixes A through E.

Task 2.0 Perform Special Emphasis Assessment - The results of this task provide special emphasis, insight, and visibility into operational areas that could influence Shuttle hardware design and other concurrent study planning.

This task was started early in the sequence so that preliminary information on potential problem areas would be available at the first performance review, with updates, as required, for the second performance review and the final report. The special emphasis assessment studies are documented in the addenda.

Task 3.0 Assess IUS and Tug Fleet Utilization - During this task, the total payload/mission (traffic) requirements for the IUS and Tug programs were assessed. The resulting data were used to optimize hardware and software procurement. Contingency planning was developed to determine the effect of selected contingencies on hardware and software requirements.

As part of this effort, existing NASA and commercial management systems were evaluated and a system for tracking and contolling resources and activities to provide management visibility was developed. Task results were documented in the IUS and Tug Fleet Utilization Subplan B.

Task 4.0 Analyze IUS/Tug Requirements for Payload Integration - In this task, IUS and Tug fleet utilization and ground operations were analyzed in support of payload accommodations and interface requirements. The analysis identified the ground operations factors affecting IUS/Tug payload accommodation. The IUS/Tug requirements data needed for payload integration were used to develop the Payload Integration Subplan C.

Task 5.0 Analyze Space Tug Site Activation - The baseline Space Tug for the period before and including site activation of ground support activities were analyzed. The use of the STS facility was analyzed to determine the ability of existing KSC facilities and GSE to support the Tug ground operations baseline. Based on trade studies of various ground operation approaches, recommended new facilities or facility modifications that best supported Tug operational requirements were made. The NASA requirements for processing and launching Tugs from WTR are shown as a delta to the KSC requirements. Activation costs are documented per the approved WBS. These analyses will be documented in a Space Tug Site Activation Subplan D.

Task 6.0 Analyze IUS/Tug Transition - The baseline IUS and Tug was analyzed for concurrent operations during the transition period. The areas of commonality between the ground operational and support systems were determined. A management plan was developed to optimize cost, schedule, and activation performance during the transition phase. Trade studies were conducted to determine common equipment and facility usage and the effect on facility, GSE, and software requirements. Schedule change options and resource requirements were evaluated. Thse analyses were documented in an IUS/Tug Transition Subplan E.

Task 7.0 Assess Results to Support Tug Acquisition Phase
The results of Tasks 1.0 through 6.0 were assessed during this task to determine factors affecting the Tug acquisition phase. Selected areas were studied to the depth necessary to provide Tug design and development recommendations. These data and recommendations are documented in Subplan F.

Task 8.0 Develop Tug Fleet and Ground Operations Schedules and Control Plan - The subplans developed in Tasks 1.0 through 7.0 were integrated and a Tug Fleet and Ground Operations Schedules and Controls Plan was developed. Each subplan optimized the study elements involved in that particular phase. The interrelationships between these individual phase requirements were analyzed and optimized for total program benefits through all program phases.

A total program summary was developed for each study element addressed and included program-level summaries for the WTR deltas. As a result of this activity, modifications were made to the individual subplans to accommodate recommended workarounds and alternatives. This task is documented in Chapters II and III of Volume II.

Task 9.0 Perform Overall Sensitivity Analysis - An overall sensitivity analysis was performed to optimize the Tug Fleet and Ground Operations Schedules and Controls Plan and the associated subplans, and assessed the impact of contingency operations on the overall plan. Results are documented in Subplan B and in the addenda.

Task 10.0 Analyze Space Tug Processing in Unclean Environment - An analysis was performed to determine the feasibility of processing the Tug in the factory clean environment and cleaning it before spacecraft/Tug mating. A comparative analysis was then performed against the baseline flow of 100K clean processing. Based on this analysis, a recommended Tug processing method (processing in a factory clean environment) was established and included in the final report as Addendum 6.

Task 11.0 Define Supporting Research and Technology (SRT) - Results of all tasks were analyzed to identify any SRT developments. Any research or technology developments that may be necessary to provide confidence that the Tug Fleet and Ground Operations Schedules and Controls Plan can be implemented are documented in Section IV of Vol II of this final report.

Task 12.0 Recommended Additional Effort - During this task the completed subplan and identified areas that require further study and developmentwere reviewed. The output of this task includes titles, descriptions, schedules, and a budget of the effort required. Our recommendations are documented in Chapter V of Vol II of this final report.

D. SIGNIFICANT RESULTS

1.0 Operations

1) Tug can be accommodated in a 157-hour land-to-launch time span.

2) Tug should be processed in the vertical position to accommodate spacecraft. The Tug itself could be processed in either horizontal or vertical position.

3) The Tug should be processed in a factory clean environment with subsequent cleaning to a visibly clean level.

4) The low bay area of the VAB provides the optimum location for the Tug Processing Facility.

2.0 Activation

1) An engineering model (Pathfinder) is required.

2) Tug site activation could have an impact on the schedule for IUS, Orbiter and launch pad.

3.0 Fleet Utilization

1) Mechanized fleet utilization planning is necessary to accommodate the many variables in the system.

2) The system must provide for contingency planning.

3) The recommended mode of transportation for the Tug is by 747 cargo pod.

4) Procurement of spares should be deferred until late in the build cycle.

5) Consideration should be given to a block build and delivery of the Tug.

4.0 Fleet Sizing

1) Total fleet size varies between 13 and 16, depending on how soon the Tug is used in an expendable mode.

2) Some variations in the mission model could reduce Tug fleet size.

3) The active Tug fleet should include a backup Tug and kick stage.

5.0 WTR Delta

1) Minimum launch capability should be provided at WTR.

2) Tugs launched from WTR should be processed and refurbished at ETR.

6.0 Tug/Payload Integration

1) Tug project does multiple payload integration.

2) A Tug User's Guide should be developed early to standardize interfaces.

3) Software verification and integration should be done in a simulation lab.

4) Level I off-Orbiter integration should be performed in the TPF test cell.

II. SYNOPSIS OF STUDY ELEMENTS

This study provides six subplans dealing with six phases or arenas of activity in the Tug program from launch site construction through the operational phase and the management of these activities. The study requires that 12 standard study elements be addressed in each subplan. Not all of the elements are applicable to each subplan; Table II-1 is a matrix depicting the relationship (contents) between the subplan and the study elements.

This synopsis provides a summary of the study elements across all of the subplans. It is a summary only; further detail can be obtained by referring to the applicable sections of each subplan.

Table II-1
Tug Fleet and Ground Operations Schedules and Controls Subplan and Study Element Relationships

Element \ Subplan	A (Task 1) Operational Subplan	B (Task 3) Fleet Utilization	C (Task 4) Payload Integration	D (Task 5) Site Activation	E (Task 6) IUS to Tug Transition	F (Task 7) Tug Acquisition
A. Ground Operations Flow	X	X	X	X	N/A	N/A
B. Facility & GSE Requirements	X	X	X	X	X	N/A
C. Transportation Requirement & Support	X	X	X	X	X	N/A
D. Operational Data Requirements	X	N/A	N/A	N/A	N/A	N/A
E. Manpower Staffing	X	X	X	X	X	N/A
F. Safety Requirements and Support	X	X	X	X	X	X
G. Fleet Utilization IUS/Tug to P/L Integration	N/A	X	N/A	N/A	N/A	N/A
H. Site Activation & Verification	N/A	N/A	N/A	X	X	N/A
I. Ground Software Development	X	X	X	X	X	X
J. Logistics/Maintenance	X	X	X	X	X	X
K. Configuration Management	X	X	N/A	X	X	N/A
L. Timeline Funding	X	X	N/A	X	X	N/A

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A. GROUND OPERATIONS FLOW

1.0 Operations Summary

The ground operations derived from the functional flow analysis are summarized in Figure II-1. Time required at processing points from the Orbiter Landing Field (OLF) to the pad are indicated at the bottom of the figure and are based on a normalized processing time after engineering model flow and activation activities have smoothed the learning curve. The 160-hour turnaround time was established through systematic analysis of each function required for refurbishment and checkout, mating operations at the Tug Processing Facility (TPF) and pad, and prelaunch and launch operations. The TPF was recommended as a common Tug maintenance and checkout facility for KSC and WTR because significant savings were indicated for this approach if WTR Tug traffic is low, as currently estimated. The shipping receipt through launch processing flow of IUS will be similar to that shown for Tug. A separate IUS processing facility will be used if Tug is processed at SAEF-1, or the IUS will be processed with Tug at the common VAB. The off-pad Tug-to-spacecraft mate shown in the flow is recommended because of the heavy traffic through the Payload Changeout Room (PCR); however, the option of vertical integration at the PCR is provided for priority payload changeout. Payload-to-Orbiter mate is recommended at the pad rather than the Orbiter Processing Facility (OPF) because our analysis shows approximately a 60-hour reduction in Tug processing time over OPF installation due to the capability of the PCR concept for KSC. Processing can be performed under 100K clean conditions using SAEF-1 as the TPF. However, it is recommended that the Tug be processed in a factory clean environment and the VAB Low Bay is the more appropriate facility for this application.

Processing operations begin at the OLF. After Orbiter landing and safing on the field and payload removal in the OPF, the Tug is moved to the TPF where refurbishment, checkout, and Tug-to-spacecraft mate occurs. When a kick stage is required, kick stage buildup, checkout, and Tug-kick stage mate also takes place in the TPF. After Tug-spacecraft mate, the Tug APS hypergolic and APS and MPS pressurants are partially loaded. The payload is then moved to the launch pad and installed in the PCR. When the Orbiter is ready for payload mate, the PCR is mated to the Orbiter, the PCR and Orbiter doors are opened, and the payload is installed in and mated to the Orbiter. Interface tests are then performed, fuel cell reactants and remaining pressurants loaded, and at T-2 hours, MPS propellant is loaded concurrent with Shuttle cryogenic propellant loading. This Tug processing flow requires 157 hours from Orbiter landing to Orbiter liftoff. In addition, the flow reflects 3 hours standby time while other operations are in progress. Of this time, the Tug is on the OLF for 2 hours, in the OPF for 17½ hours, and in the TPF for 97 hours. Movement to the pad, installation in the PCR, and Tug standby require 20½ hours. The payload is installed in the Orbiter at T-23 hours. The crew size to perform these operations for one Tug cycle only on a two-shift basis is 80 personnel.

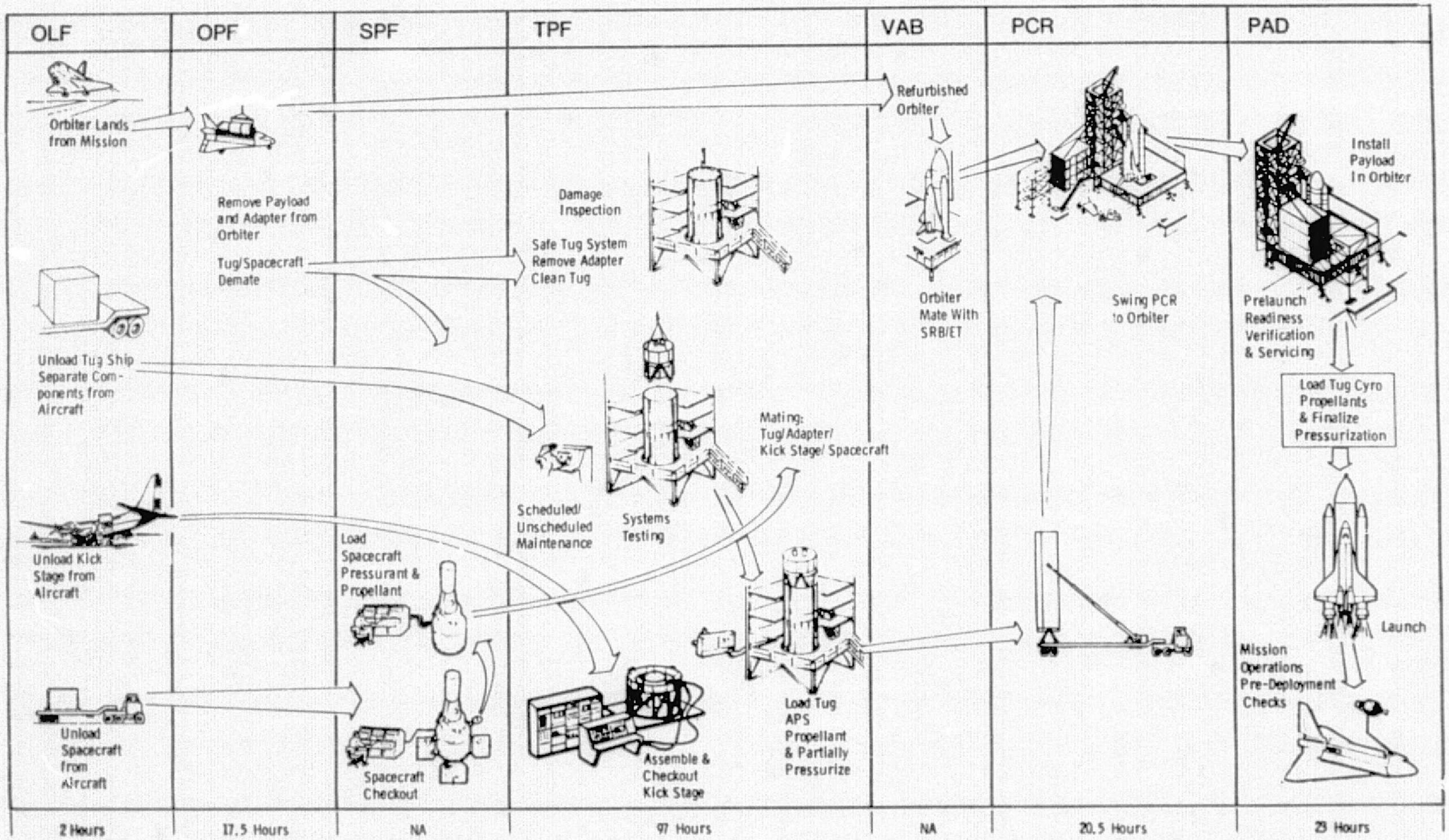


Figure II-1 Tug Ground Operations Flow

2.0 Contingency Planning and Control

The ground operations flow developed is "green light" and makes no provisions for contingency planning. Efficient Tug fleet utilization must consider the real-world effect of contingencies and make provisions in the system for handling them if they occur.

The contingencies fall into three categories: (1) system element "no go"; (2) system element "no show"; and (3) programmatic changes (priority payloads, schedule changes, etc). Each contingency has been analyzed and documented in Subplan B, IUS and Tug Fleet Utilization, with indicated alternative actions if contingencies occur during the operational flow.

3.0 Payload Operations Impact

Spacecraft mating with the Tug in the TPF will occur 63 hours before launch with Spacecraft mating and integrated checkout requiring 14 hours. The payload is installed in the Orbiter bay 23 hours before launch, followed by 6.5 hours of prelaunch checkout. The payload is functionally ready for launch 12 hours before launch with final servicing the only remaining activity. Postmission Tug/spacecraft demate will take place at the OPF.

4.0 Engineering Model Flow and Flight Article Preparation

A Tug engineering model, ideally an upgraded version of a test article, will be used at KSC prior to arrival of the first flight article. The model flow will follow the planned Tug operational flow as closely as possible and will be used to identify, document, and resolve GSE and facility interface problems. The accuracy and adequacy of Tug operational procedures and the LPS control and monitoring software programs will be verified. Checkout and handling personnel will be trained during the model flow and final crew certifications will be performed. Interface compatibility between Tug and its adapter, kick stage, and spacecraft, as well as with the Orbiter, will be determined. Procedures, methodology, and hardware will be developed to minimize operational flow time for planned and contingency functions. Transportation and handling procedures and support equipment, primarily the cargo canister, will be verified. Model flow activities are planned for a one-shift, five-day week operation that would require 18 weeks to complete. An additional eight weeks would be planned for contingency operations.

The first flight article will be used in somewhat the same manner as the engineering model. This approach will require that the first flight article be delivered to KSC 90 days before launch. The activities planned for the first flight article will require 12 weeks based on two shifts per day, five days per week operation.

B. FACILITY AND GSE REQUIREMENTS

1.0 Facilities

Facility requirements in support of the ground operations flow are summarized in Table II-2. Facility significant functions within the flow are listed with generic requirements identified. Our recommendations for use of specific existing facilities at ETR to meet these requirements are not included in this summary but are listed in this volume under Section H, Site Activation and Verification and in Subplan D, Space Tug Site Activation. It should be noted in the table that the Tug traffic model and contingency provisions impose additional requirements for storage of up to four Tugs and two adapters in a temperature and humidity controlled area at the TPF.

Spacecraft will be mated with the Tug and the integrated payload checked out in a Class 100,000 clean area of the TPF. The PCR will be maintained Class 100,000 clean to support Orbiter bay mating and removal of nonflight items from the spacecraft.

The existing facility considered the most likely candidate for modification to a TPF for Class 100,000 clean Tug processing is SAEF-1. The alternative facility considered in this study was the VAB low bay area, cells 1 and 2. The primary advantages and disadvantages of using each of these facilities for Tug processing in a Class 100,000 clean environment is shown in Figure II-2.

If the SAEF-1 should be selected for IUS processing, it could not be activated to a TPF because the size of the facility would not permit ongoing IUS operation and Tug site activation without interference. Therefore, IUS processing should be accomplished some place other than SAEF-1. Since the IUS cannot be readily accommodated in SAEF-1, all IUS processing after Tug IOC should be continued in the same location as accomplished before TPF activation.

The existing facility considered the most likely candidate for modification to a TPF for factory clean Tug processing is the VAB low bay area. The alternative facility considered in this study was the SAEF-1. The use of SAEF-1 with its Class 100,000 clean capability for factory clean operations is poor utilization of KSC facilities. The advantages and disadvantages of using each of these facilities for Tug processing in a factory clean environment is shown on Figure II-3.

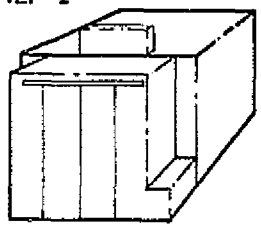
The VAB low bay is of sufficient size and capability that it would accommodate both the IUS and Tug processing. A summary of the assessment to determine facility and GSE commonality between IUS and Tug operations is presented in Figure II-4.

Table II-2 Facility Requirements

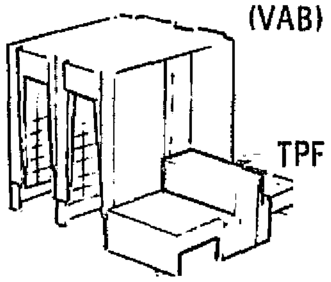
Facility	Functions	Facility Requirements
Orbiter Processing Facility (OP' (Transfer Ai))	Offload payload from Orbiter	Existing transfer aisle
OPF (Tug Demate Area)	Demate Tug/spacecraft, remove COMSEC equipment	Single cell located in OPF, controlled access, LPS terminal
Tug Processing Facility (TPF) (Airlock)	Receive, inspect, damage inspection, Tug safing, cleaning, demate Tug/ adapter	Controlled access area, MPS and APS purge and vent provisions, personnel safety provisions, LPS terminal, 100K* class clean room
TPF (Tug Maintenance and Checkout Area)	Tug refurbish, checkout and buildup for mission mate spacecraft to Tug and checkout	Two bay, controlled access, 100K clean* room, tempest compatible, parasitic antenna, LPS terminal, OIS communications
TPF (Deployment Adapter Maintenance and Checkout Area)	Deployment adapter Refurbish and checkout in preparation for mate with Tug	Two bay, 100K clean room*, OIS communication, LPS terminal
TPF (Kick Stage Buildup and Checkout Area)	Kick stage buildup and check in preparation for mission	Single bay, 100K clean room*, OIS communications, LPS terminal
TPF (Storable Propellant Loading Area)	Load Tug APS propellants and partial pressurant load	Single bay, 100K clean room*, OIS communications, LPS terminal, controlled access, personnel safety provisions
TPF (Tug and Adapter Storage Area)	Store Tug and adapter until required for mission	Temperature and humidity controlled area for storing four Tugs and two adapters
TPF (Tug Hardware Bonded Storage Area)	Store Tug system hardware until required to support refurbishment activities	Temperature- and humidity-controlled storage area, storage racks, bins, shelves for Tug components
TPF (Engine Preparation and Service Area)	Major engine overhaul and refurbishment	Controlled access 100K clean room*, LPS terminal
TPF (Battery/Fuel Cell Service Area)	Battery and fuel cell preparation and refurbish	Controlled access 100K clean room, LPS terminal, hydrogen and oxygen vents
TPF (GSE Checkout and Maintenance)	Periodic calibration and maintenance of GSE	100K clean room*, bench calibration areas
TPF (Avionics Checkout and Maintenance)	Avionic LRU refurbishment and checkout	100K clean room*, LPS terminal, stable platform for optical alignment, LRU refurbishment area
TPF (Paint Shop)	Refurbish Tug LRU/segments	100K compatible
TPF (Canister Load Area)	Load payload into canister for transport	100K clean area*, controlled access, OIS communication
Payload Changeout Room	Payload transfer (canister to PCR), buildup and checkout, transfer (PCR to Orbiter bay)	Retractable 100K clean room, LPS terminal, payload handling device, controlled access, tempest compatible

* 100K clean was baseline.
Factory clean is recommendation.

SAEF-1



(VAB)

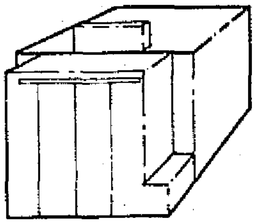


	SAEF-1	VAB
Pro:	Existing Class 100,000 Area Labs & Shops Available Existing Airlock (Mod) Cranes Have Capacity Leak Check Compatible	Sufficient Height For Vertical Processing Can Accommodate IUS & Tug Work Platforms Available Office, Shop, Lab & Storage Space Available Cranes Have Capacity
Con:	Airlock Needs Height Increase Extensive Mods In Clean Area New Bldg Req'd For Offices & Storage IUS Cannot Be Easily Accommodated	Extensive & Costly Mods to Make 100,000 Clean No Airlock Cells Not Enclosed Cells Not Leak Check Compatible

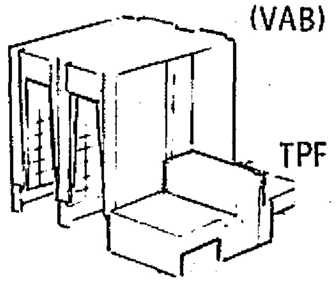
Conclusion: For Class 100,0uu Clean Tug Processing Use SAEF-1

Figure II-2 Class 100K Clean TPF Location Comparison

SAEF-1



(VAB)



	SAEF-1	VAB
Pro:	Leak Check Compatible Final Wipe-Down Area Exists Cranes Have Capacity Labs & Shops Available	Sufficient Height For Vertical Processing Work Platforms Available (Mod) Can Accommodate IUS & Tug Office, Shop, Lab & Storage Space Available Cranes Have Capacity
Con:	Poor Use Of 100,000 Clean Area Airlock Mod For Vertical Processing IUS Cannot Be Accommodated Easily New Bldg Reqd For Storage, Offices	Cells Not Enclosed Bldg Not Leak Check Compatible Mod Reqd To Cell Platforms Mod Req'd To Provide Clean Areas Around S/C When Mated

Conclusion: For Factory Clean Tug Processing Use VAB Low Bay

Figure II-3 Factory Clean TPF Location Comparison

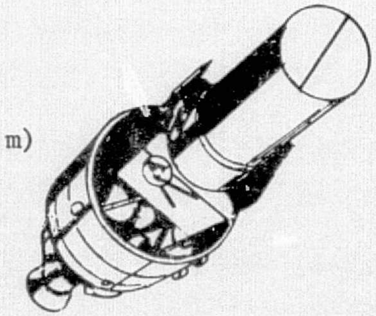
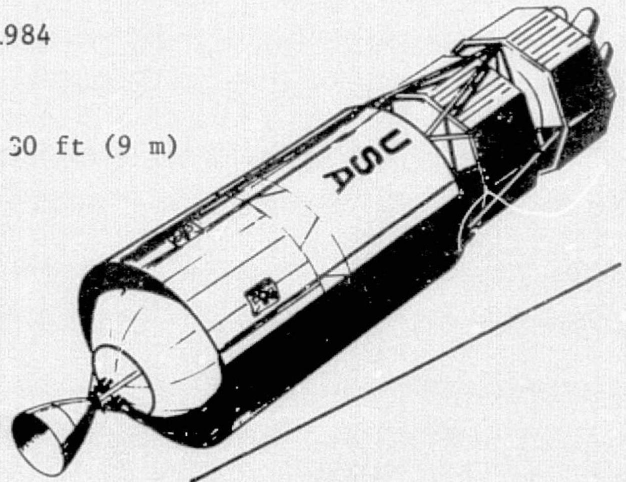
	IUS 1981-1984 Length 19.5 ft (5.9 m)	Tug 1984 Length 30 ft (9 m)	
			
Checkout Cells	(1) 25 x 25 ft (7.5 x 7.5 m) with 10 ft (3 m) Cutouts	(2) 35 x 25 ft (10.6 x 7.5 m) with 15 ft (4.5 m) Cutouts	Could Conceivably Be Made Common With Adjustable Cut Outs and Platform Levels
Service/Deservice/ Pressure GSE	Hypergolic Set	Cryogenic Set	No Commonality
Transportation and Handling GSE	Accommodate 10 ft D x 19.5 ft L (3 x 5.9 m)	Accommodate 15 ft D x 30 ft L (4.5 x 9 m)	Possible Adjustable for Commonality But Not Practical
Avionics Checkout GSE	Van Mounted GSE	Primarily LPS	No Commonality
Orbiter Fluid Interfaces	Hypergolic	Cryogenic	No Commonality
Kickstage C/O Areas	Solid, 2 Sizes	Solid, 2 Sizes	Common
Engine C/O and Service Area	30 x 30 ft Hypergolic (9 x 9 m)	25 x 25 ft Cryogenic (7.5 x 7.5 m)	Could Possibly Have Some Common Capabilities
LCC	IUS Unique	Tug Unique	No Commonality

Figure II-4 Facilities/GSE Commonality Assessment IUS/Tug

In the TPF, areas of IUS/Tug commonality are primarily LRU and GSE checkout areas and shop and support areas, which are not sensitive or dedicated to the type of hardware processed in that area. Due to the difference in size of the Tug and IUS, two different refurbishment and checkout cell sizes are required in the TPF. It is possible to make cells convertible to either Tug or IUS; however, time to convert and the traffic model indicate that the best approach would be to provide two Tug cells and one IUS cell in a combined facility to support the NASA and non-NASA/DOD traffic.

Because the type of kick stages currently identified for the Tug are the same as those used by the IUS, the kick stage buildup/checkout area can be common for the IUS and Tug. This is especially true because the kick stage is assumed to be developed by one agency for use on both stages and the current traffic model requires only nine Tug kick stages, while the IUS requires 14 in the expendable mode or 65 in the reusable mode during the life of the Shuttle program.

2.0 Ground Support Equipment (GSE)

Items of GSE required to support single cycle Tug processing are summarized in Table II-3. Identification numbers shown in the left hand column may be correlated with the GSE Requirements Specification Data Sheets which may be found in Appendix B and which provide expanded GSE information. Functional locations of the GSE identified are indicated in the right-hand columns of the summary.

The green light flow and the traffic model combine to indicate that one set of GSE is all that is required to accommodate all Tug flights. All but three GSE items are used less than 50% of the time during a Tug processing cycle and the mean usage is less than 15% of the time giving ample flexibility for dual Tug usage for uneven launch centers. The additional GSE which should be provided are Tug workstand, inspection workstand, electrical power supply, control and data acquisition console, and memory load and verify unit. The spacecraft agency will furnish spacecraft peculiar GSE required for handling or checkout within the operational flow, over and above the LPS. GSE required for site activation will be used for verification.

Table II-3 Ground Support Equipment Matrix

ID No.	Nomenclature Avionics	OPF Transfer Aisle	OPF Tug Demate	TPF Airlock	TPF Tug Maint & C/O Area	TPF Adapter Maint & C/O	TPF KS Buildup & C/O	TPF Propellant Load	TPF Offline Support	WTR
A-001	Electrical Power Supply		x	x	x		x			x
A-002	Electrical Power Test Set				x		x			
A-003	Electrical Load Banks				x		x			
A-004	Battery Test Set								x	
A-005	Battery Charger				x					x
A-006	Communication Test and Checkout Equipment				x		x			
A-007	Guidance and Navigation Test and Checkout Equipment				x		x			
A-008	Control and Data Acquisition Console			x	x		x			x
A-009	Memory Load and Verify Unit				x		x			x
A-010	Electronics Calibration Equipment				x					
A-011	Orbiter Cable Simulator				x					x
A-012	Umbilical Simulator				x					x
A-013	Star Sensor Simulator				x		x			
A-014	Tug/Spacecraft Simulator					x				
A-015	Fuel Cell Dummy Load Unit								x	
A-016	Ordnance Event Verification Cables				x					x
A-017	Latch Mechanism Test Set				x					
A-018	Hardware Interface Module (HIM)				x					x

Table II-3 (cont)

ID No.	Handling and Transportation	Transfer Aisle	Tug Demate	Airlock	Tug Maint & C/O Area	Adapter Maint & C/O	KS Buildup & C/O	Propellant Load	Offline Support	WTR
H-001	Tug Workstand			x	x					x
H-002	Engine Workstand								x	
H-003	Deployment Adapter Workstand			x		x				
H-004	Tug Transportation Dolly			x	x					
H-005	Cargo Bay Work Platform Set	x								x
H-006	Internal Platform			x	x					
H-007	Deployment Adapter Dolly			x						
H-008	Deployment Adapter Protective Cover Kit								x	
H-009	Spacecraft Adapter Transport/ Storage Pallet			x	x					
H-010	Kick Stage Protective Cover Kit			x						
H-011	Kick Stage Motor Cradle			x						
H-012	Kick Stage Buildup/Checkout Fixture						x			
H-013	Kick Stage SRM Storage Pallet								x	
H-014	Kick Stage Storage Pallet								x	
H-015	Tug Storage Pallet								x	
H-016	Tug Engine Handling Kit								x	
H-017	Deployment Adapter Storage Pallet								x	
H-018	Handling Sling Kit	x		x	x		x			x
H-019	Tug Protective Cover Kit		x							x
H-020	Tug Desiccant Kit								x	
H-021	Battery Handling Kit			x	x					x
H-022	Air Carry Tie Down Kit								x	x
H-023	Transport Data Recorder								x	
H-024	Tug Transtainer	x		x	x					x
H-025	Tug Lifting Rings	x		x	x					x
H-026	Inspection Workstands		x	x	x					x
H-027	Spacecraft Docking Simulator				x					
H-028	Kick Stage Transtainer						x			
H-029	Vertical Adapter									x
H-030	Kick Stage Motor Support Fixture			x						

Table II-3 (concl)

ID No.	Propulsion and Mechanical	Transfer Aisle	Tug Demate	Airlock	Tug Maint & C/O Area	Adapter Maint & C/O	KS Buildup & C/O	Propellant Load	Offline Support	WTR
P-001	Aft Umbilical Servicing Unit								x	x
P-002	Fuel Cell GN_2 Purge Unit			x						x
P-003	Fuel Cell Water Supply Unit								x	
P-004	Fuel Cell GH_2 Accumulator Charge Unit								x	
P-005	Fuel Cell GO_2 Accumulator Charge Unit								x	
P-006	Engine Alignment Kit				x					
P-007	Tug Engine Actuator Servicing Kit								x	
P-008	Alignment Kit				x					
P-009	Insulation Purge and Metering Unit			x	x				x	x
P-010	Propellant Supply and Transfer Unit								x	
P-011	APS Propellant Control Set			x	x		x	x		x
P-012	APS Propellant Supply and Transfer Unit								x	x
P-013	Preservation Unit								x	
P-014	Vacuum Pump and Gauge Unit				x					
P-015	Hydraulic Servicer				x					
P-016	Pressurization Control Set			x	x	x		x		x
P-017	Decontamination Unit APS								x	
P-018	Vacuum Pump and Gauge Unit APS							x		x
P-019	Thermal Control Servicing Set					x				
P-020	Hot GN_2 Purge Unit					x				
	<u>Structural</u>									
S-001	Ultrasonic Scan Unit					x				
S-002	Radiography Unit					x				

Because of size and system configuration differences, unique GSE will be required for Tug and IUS. The Tug will require a hydrogen burn stack and an external oxygen vent, while the IUS will require oxidizer and fuel vapor combustion units. The PCR IUS and Tug work platforms would be a part of a total payload platform set. Those platforms, to be used for the IUS and Tug, should be designed to be adjustable and interchangeable. The ground payload manipulator will be common to IUS, Tug, and non-IUS/Tug payloads. Both the IUS and Tug have helium in their pressurization systems. Therefore, the PCR/pad helium supply/service system to the Orbiter interface can be a common system. The Tug will require two major additions to the PCR/pad, the cryogenics loading system for Tug, and the fuel cell reactant loading for Tug fuel cells. The IUS will not require either of these systems at the pad.

IUS/Tug have very little commonality because the Tug will use the LPS for checkout and van-mounted GSE will be used for IUS checkout. The servicing/pressurization GSE supporting the Tug and IUS will be different. The Tug MPS operating pressure is 17 to 18 psia (11.7×10^4 - 12.4×10^4 N/m^2) while the IUS MPS is a 160 psia (1.1×10^6 N/m^2) system. This GSE would also be procured by two government agencies from their respective contractors. Fuel cell reactants servicing GSE would be peculiar to the Tug, while APS servicing/pressurization GSE could be made common for both stages because the propellant is the same. Because of size differences, the handling GSE will also be different.

The LCC would require consoles and racks that are unique to the IUS and unique to the Tug for propellant loading and systems monitoring. Therefore, sufficient area is required in the LCC for both the IUS and Tug propellant loading and system monitor consoles/racks.

C. TRANSPORTATION/HANDLING REQUIREMENTS AND SUPPORT

1.0 Air Transport

The IUS, Tug, kick stage, and spacecraft payload modules plus their ship loose and support equipment must be transported from manufacturer to KSC, between KSC and WTR, and from alternate/contingency landing sites to KSC. Unlike the 10-foot diameter of IUS, kick stage, and some spacecraft, the 15-foot diameter of Tug presents an outsized shipping configuration that precludes easy transport by road or rail. The probability of an inland manufacturer, plus the cost and excessive time in transport, does not support marine transportation. Air transport, recommended for Tug, will also accomplish one-day delivery for domestic shipments of IUS, kick stage, or spacecraft, and minimizes return time from contingency sites.

Although the C-5A and a variety of Guppy aircraft can handle ten-foot diameter modules, Tug would require the Super Guppy and its availability is questionable. Induced loads and negative scheduling aspects, i.e., ship an Orbiter each time a payload module is shipped, rule out shipment in the Orbiter piggyback on the B-747. Use of the B-747 with a piggyback cargo canister, which could be optimized to handle all payload modules, is a viable approach to common transportation requirements and provides maximum use of the B-747 aircraft, as well as the cargo canister.

Typical use of the B-747 and cargo canister concept is represented in the KSC to WTR Tug transportation flow shown in Figure II-5. Through common design in transportation support equipment, the major aspects of this flow could apply to IUS, kick stage, spacecraft, or integrated payloads, and would be basically the same for moves from the manufacturer or contingency landing sites to KSC with the alternative use of mobile cranes instead of the Mate-Demate Facility (MDF). The flow shown starts with Tug flight preparation at the TPF. The Tug is then loaded into a cargo canister on its transporter and towed to the airfield. The transporter is positioned in the MDF, the canister is disconnected from its transporter and raised to aircraft loading position, the transporter is removed, the B-747 positioned, and the canister attached to the B-747. The canister with Tug inside is flown piggyback on the B-747 to WTR where it is removed by MDF and towed to the PPR.

2.0 Ground Handling

Ground operations handling begins after the mission with removal of the payload from the Orbiter bay at the OPF, as shown in Figure II-6. After separation, the spacecraft and Tug are transported to their respective processing facilities. At the TPF the Tug is removed from its transporter by crane, an aft pivoting adapter is attached, and the Tug is oriented to a vertical position and moved to an airlock precheckout stand. After precheckout operations, a payload manipulator moves the Tug to its cell in the checkout area. A processed Spacecraft is transported to the airlock area, transferred by payload manipulator to the checkout area cell, and installed by crane on the Tug or Kick Stage. Interface tests are completed and the manipulator moves the integrated payload to the airlock if the SAEF-1 building is used. APS loading is performed in the airlock at SAEF-1 or in the test cells at VAB. At the completion of APS loading, the manipulator loads the payload into the ground configured cargo canister on its transporter at a sealed transfer interface in the airlock door (SAEF-1) or at the checkout cell door (VAB). The canister, with enclosed payload, is then transported vertically to the PCR. Transfer of the canister from its transporter to PCR guide rails is accomplished. The canister is drawn up the rails by the PCR overhead crane and positioned at the seal interface of the PCR transfer door. The PCR manipulator removes the payload from the canister and positions it in the PCR.

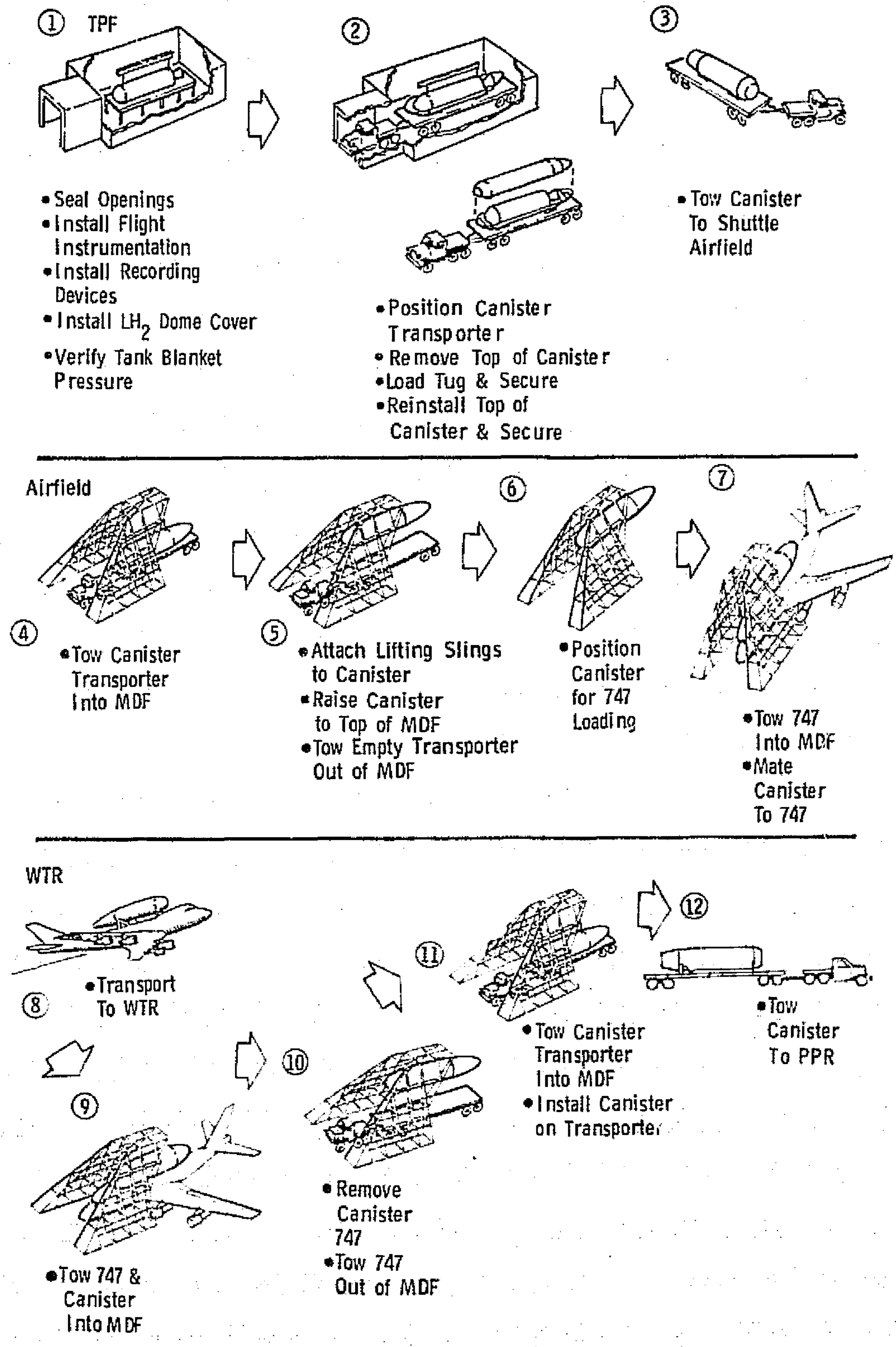
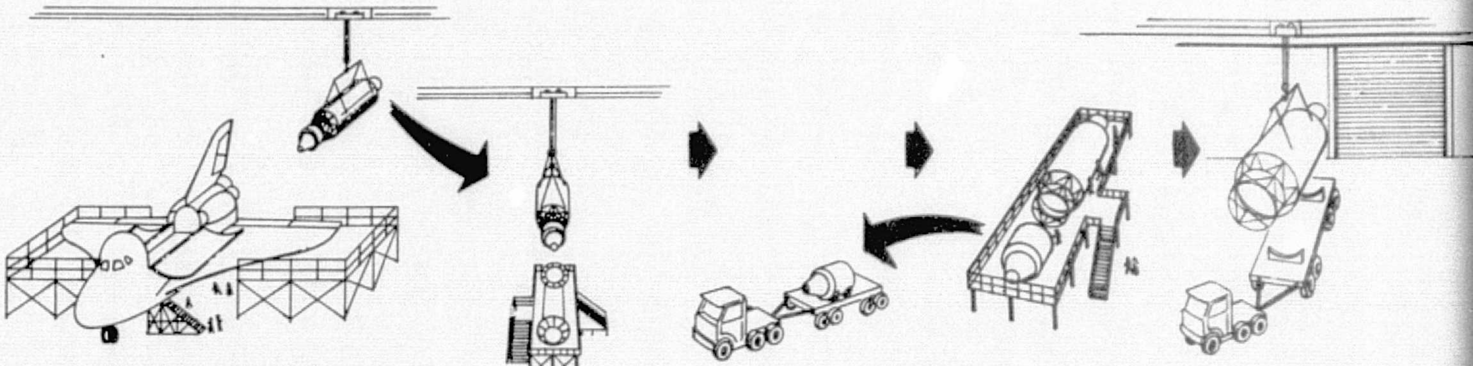
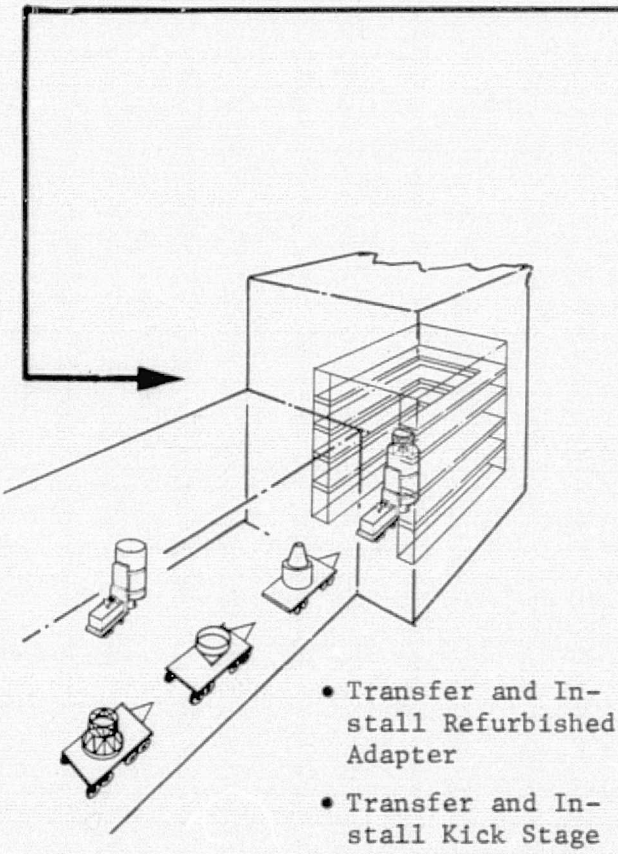


Figure II-5 KSC to WTR Transportation Flow

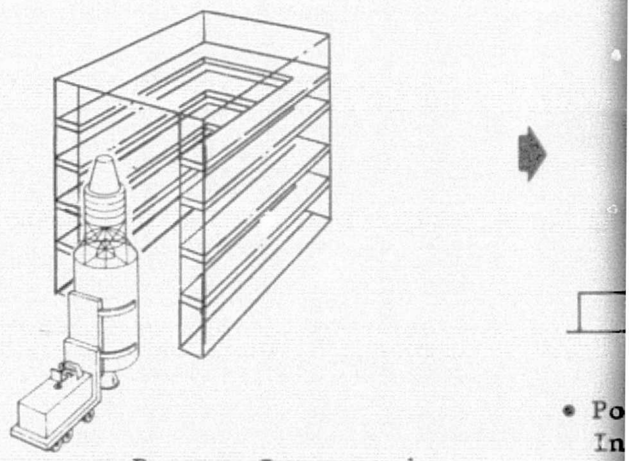


- Remove Payload from Orbiter Bay at OPF
- Place Payload On Demate Fixture

- Separate Tug and Payload On Demate Fixture
- Place Spacecraft on Spacecraft Transporter
- Place Tug On Ground Transporter



- Transfer and Install Refurbished Adapter
- Transfer and Install Kick Stage
- Transfer and Install Spacecraft
- Perform Interface Tests



- Prepare Integrated Payload for Movement
- Remove Integrated Payload from Checkout Cell with Manipulator
- Transfer to Airlock Area

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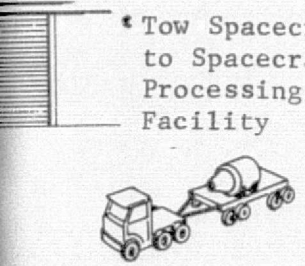
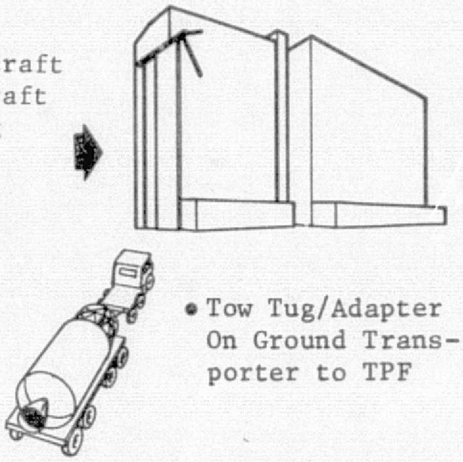
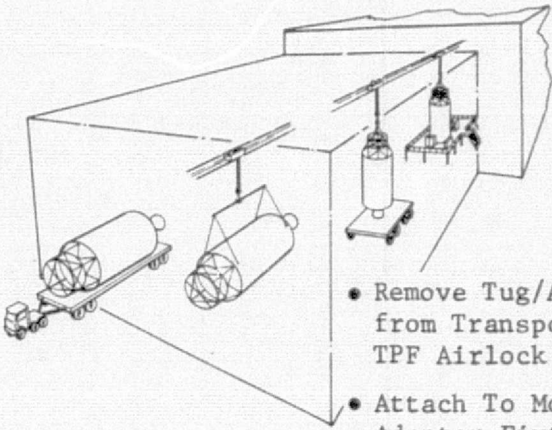


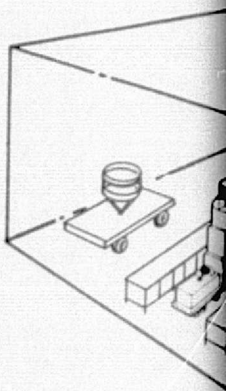
* Tow Spacecraft to Spacecraft Processing Facility

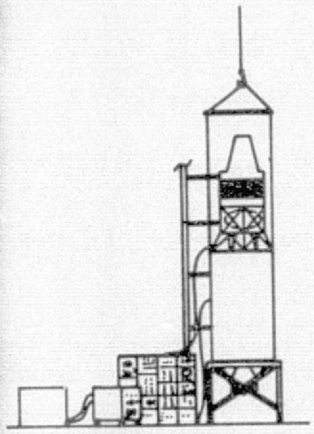


* Tow Tug/Adapter On Ground Transporter to TPF

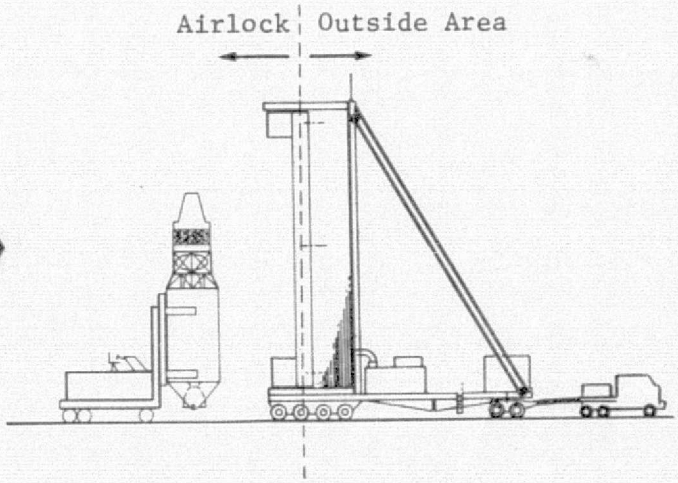


* Remove Tug/Adapter from Transporter In TPF Airlock Area
* Attach To Mobile Tug Adapter Fixture
* Pivot To Vertical Position
* Move To Airlock Precheckout Stand

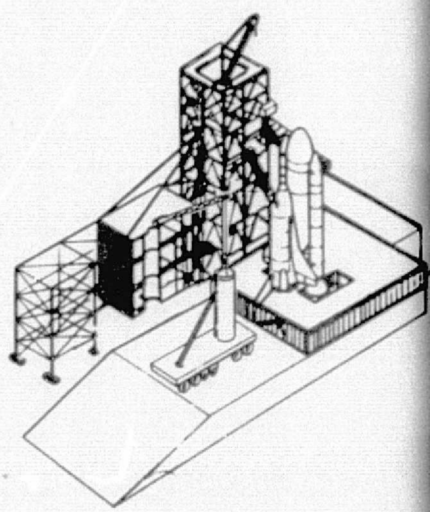




* Position Payload In Precheckout Stand
* Perform APS Loading



* Position Cargo Canister Transporter At Outside Door of Airlock
* Hydraulically Elevate Cargo Canister To Vertical Position
* Position Canister To Seal with Airlock Transfer Door
* Remove Canister Cover from Inside Airlock
* Install Payload In Cargo Canister
* Transfer To Pad



* Prepare PCR To Re
Payload
* Position Cargo Ca
Transporter To PC
fer Rails
* Draw Canister Up
Payload Transport
* Remove Payload fr
with PCR Manipula

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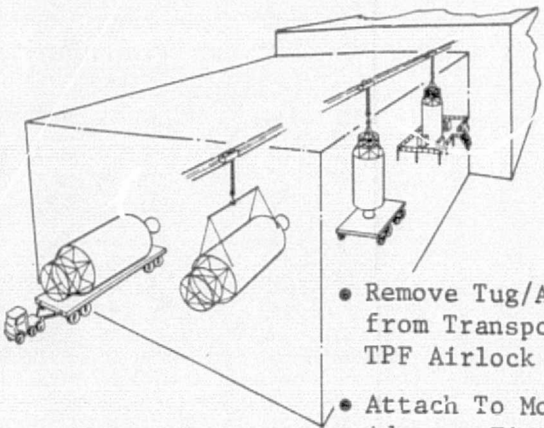
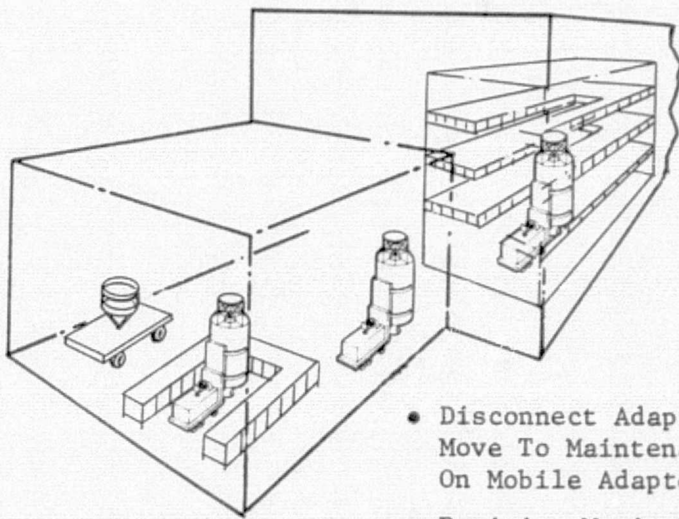
FOLDOUT FRAME 2

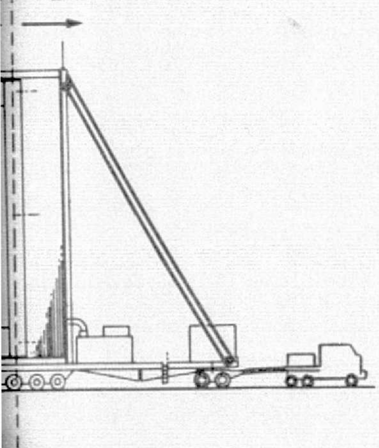


- Remove Tug/Adapter from Transporter In TPF Airlock Area
- Attach To Mobile Tug Adapter Fixture
- Pivot To Vertical Position
- Move To Airlock Precheckout Stand



- Disconnect Adapter and Move To Maintenance Area On Mobile Adapter Fixture
- Position Manipulator To Receive Tug At Precheckout Stand
- Transport Tug with Manipulator To Checkout Area Cell
- Install Tug In Checkout Cell

Outside Area



Canister Transporter
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Elevate Cargo Canister
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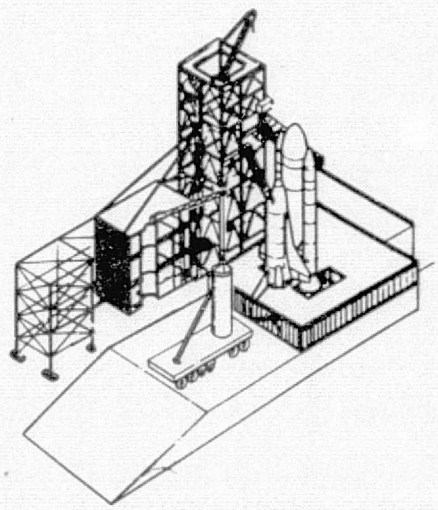
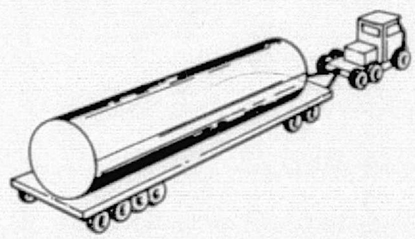


- Prepare PCR To Receive Payload
- Position Cargo Canister Transporter To PCR Transfer Rails
- Draw Canister Up Rails To Payload Transporter Position
- Remove Payload from Canister with PCR Manipulator



- Lower Empty Cargo Canister To Horizontal Position On Transporter
- Tow Cargo Canister On Transporter To Storage/Next Point of Use

Figure II-6 Normal Ground Movement at KSC

3.0 Transportation/Handling Equipment

The cargo canister and its transporter are envisioned as MMSE with potential for common application to payload modules as well as airborne and ground transportation. The canister could have an airborne configuration with aerodynamic fairings installed and a ground configuration with fairings removed, and would have internal design very similar to the Orbiter payload bay. The IUS could be carried in the canister through its interfacing cradle. Spacecraft interface with the canister could be as planned for the Orbiter payload bay with modular adaptation to carry them vertically if height did not exceed 15 feet. In its ground configuration the canister could see common use for movements of the integrated payload from TPF to PCR.

The MDF can be used for cargo canister handling at KSC and WTR and provides a far more secure and time-saving approach to canister loading than the use of mobile cranes and access stands or personnel positioning devices. Because of the high cost of these fixtures the recommended relocation of the MDFs currently planned is for Palmdale and Edwards AFB. Because of the size and weight of these fixtures, detailed feasibility and cost studies will be required to establish their use at KSC, WTR, or contingency landing sites. Based on early availability, the MDF could be used to handle canisters for IUS shipments. It could also see multiple use for canister shipments of kick stage, spacecraft, and integrated payloads.

The payload manipulator described for use at the TPF can provide multiple handling capability for Tug, IUS, kick stage, and spacecraft, as well as for the integrated payload. The manipulator can interface with the IUS through its cradle. Similar cradles can be used for handling the kick stage and spacecraft, or the manipulator itself can be designed to accept loads of different diameter. Although the TPF manipulator is envisioned as a mobile, wheeled device and the PCR unit is probably operated on a track, the manipulator arms and load/attach points could be common design.

4.0 Transportation/Handling Management

Transportation management will generate payload module and integrated payload transportation schedules and coordinate availability of the B-747 aircraft and the support equipment necessary for shipping operations. Because of priority scheduling of the B-747, overlap of manufacturer's deliveries and operational transfers to WTR, and the probability of alternative or contingency site return transportation, a computerized transportation scheduling segment has been recommended for the Tug Fleet Utilization Planning System. Transportation activities will be controlled by transportation plans covering major requirements, such as shipment from the manufacturer to KSC, ferry service between KSC and WTR, and return shipments from

alternative or contingency landing sites. Individual delivery plans with sequence charts and detailed handling procedures will be developed for specific shipments to implement overall transportation plans. O&M manuals should contain the procedures necessary for operation and maintenance of the transportation support equipment.

The spacecraft agency will be responsible for spacecraft delivery to KSC and for ground transportation and handling operations before the spacecraft is mated with the IUS/Tug or kick stage at the TPF. After mate, transportation and handling operations for the integrated payload are the responsibility of the IUS/Tug processing agency and do not revert back to the Spacecraft agency until postmission or alternative/contingency landing demate of the spacecraft from the IUS/Tug. Spacecraft transportation and handling requirements are developed by the spacecraft agency and incorporated into the KSC ground operations processing flow and transportation and movement plans.

The transportation/handling flow described above will be verified during the site activation phase using the Tug engineering model and available kick stage/spacecraft test article. Transportation support equipment, such as the cargo canister, transporter, and MPF, will be verified under actual handling conditions. Transportation plans and individual movement plans/procedures will be verified in use during shipment of the engineering model from the manufacturer to KSC and from KSC to WTR. Problems or work-arounds encountered during site activation transportation/handling operations will be red lined in the procedures and fed back into the transportation requirements analysis and transportation plans for update in preparation for the first flight article. The first flight article flow will reverify transportation and handling operations and the procedures used to accomplish them.

D. OPERATIONAL DATA REQUIREMENTS

1.0 Objectives and Approach

The primary objective in the selection or establishment of operational flight instrumentation (OFI) requirements was to maximize the use of condition-monitoring maintenance techniques while using assessment techniques that would provide maximum health and trend data without adding excessive data transducers.

The present baseline Tug configuration has inherent capabilities to accomplish the above objectives and is within the data management and measurements subsystems. The central processor of the data management subsystem provides an almost limitless self-test and data storage capability which, with proper programming and memory sizing, can provide continuous hardware test, monitoring, and trend predictions as a function of normal operational commands.

An assessment was made to determine the minimum flight operational instrumentation and caution and warning requirements for the Tug and provide adequate data for support of maintenance activities and assurance of safe operations. This assessment used both Tug and Orbiter baseline data as well as various other contractor's data to establish the recommended minimum OFI and C&W requirements. The fundamental assessment approach was to consider the minimum flight data required to support the last flight as best test concept. The assessment included an analysis of a contingent hazardous condition that should be displayed and a definition of control capability requirements.

The OFI requirements matrix (Table II-4) displays the present measurement types and numbers that are estimated to fulfill the above objectives. Note that of the 1332 measurements indicated on the matrix, 1037 are evaluation of normal operational commands or self-test data (these measurements are identified as on-board checkout and current signature measurement) and the remaining 285 measurements are provided by various transducers or instruments located throughout the Tug.

2.0 Tug OFI Requirements

The current Tug baseline configuration definition contained in MSFC 68M00039-2 provides an inherent capability within the data management, measurement, and computer subsystems to provide data that will support a condition-monitoring maintenance technique as well as give adequate contingency/hazardous conditions indications. Table II-4 provides an estimate of the minimum numbers and types of measurements that should be made. This tabulation shows both C&W hardwire and flight operations monitoring capability. As the design of the Tug and Orbiter mature, these measurements will have to be reviewed and updated as required. The only apparent problem at this early date is associated with C&W response capability. The present philosophy related with C&W capabilities seems to be one that, if no obvious reaction to a hazardous condition exists, then ignore it. This type of response early in the design phase could cause serious cost and redesign problems during the operational phase. Where response inadequacies existed in certain C&W monitored conditions, design recommendations were made in either Tug design impact or Orbiter design impact.

Table II-4 OFI Requirements Matrix

System-Subsystem \ OFI Sensor Type	Temperature	Pressure	Vibration	Shock	On-board Checkout	Flow	Position	Voltage	Liquid Level	Depletion L-L	Hydrogen Leak	Oxygen Leak	Residual Gas Analysis	Contamination	Speed RPM	Current Signature	Totals
Structures	8	4	9	8							2	2	2	4			39
Forward Skirt			3	3													6
Main Skirt			3	3							2	2	2				12
Liquid Hydrogen Tank	4	2												2			8
Liquid Oxygen Tank	4	2												2			8
Aft Adapter			3	2													5
Propulsion	8	35	2		26	6	32	7	8	4					4	76	208
Main Engine	3	6	2				3								2		16
Feed-Fill-Drain-Vent LH	1				1		7	2								8	19
Feed-Fill-Drain-Vent LO	1				1		5	2								6	15
Pressurization		6					8									13	27
Hydraulic						2	4	1	2						2	1	12
Propellant Load-Measure								2	6	4							12
APS	3	23			24	4	5									48	107
Thermal Control	66	8			5	5	6		2						1	8	101
Active T/C	12	2			5	3	3		2						1	3	31
Passive T/C	30																30
Insulation-Purge	24	6				2	3									5	40
Avionics	8				922		10	24	4	2	1	1		2			974
Nav.-Guid.-Control					240												240
Data Management					256												256
Communications					69												69
Measurements					229												229
Electrical Power Distr.	8				128		10	24	4	2	1	1		2			180
Totals	90	47	11	8	953	11	48	31	14	6	3	3	2	6	5	84	1322

3.0 Transportation Data/Instrumentation Requirements

During the transportation operations of the Tug from the manufacturer, WTR, ETR, or a contingency site, certain data/instrumentation will be required. These include shock, vibration, temperature, and pressure. Shock and vibration will be monitored primarily at the attachment points to measure dynamic loads imposed by handling and air transport. Temperature and pressure measurements will be critical to establish the integrity on the tanks and temperature sensitivity device during the transportation functions. Inasmuch as these measurements are also required during normal ground and flight operations, their requirements should be integrated with normal OFI requirements wherever possible.

4.0 Shuttle/Orbiter Design Impact

During this assessment, the defined operational data requi . ents indicated only a need for selected reaction capabilities to be added to the Orbiter side of the interface.

5.0 Development Flight Instrumentation

The defined instrumentation are estimated to conceivably increase by a factor of 1.5 because of the required acquisition of dynamic, static, and thermal loading assessment needed to complete design evaluations during early Tug flights.

E. MANPOWER STAFFING

1.0 Operational Crew Composition

The overall Tug ETR launch site crew size and makeup was determined through an analysis of the stick and ball chart contained in subplan A. The organization shown in Figure II-7 would be typical for the refurbishment/checkout of a single Tug at ETR on a two-shift-per-day basis. Analysis of the traffic model has shown that this "single cycle" operations crew is large enough to fulfill the ETR requirements. WTR operations impose additional requirements and the total ETR/WTR operations crew requirement is shown in Figure II-8. This figure represents a crew of 107 people stationed permanently at ETR with seven additional people stationed at WTR. An operations crew, from ETR personnel, would follow the Tug to WTR and return to ETR following launch. In addition to the operations crew, fleet management requires a typical organization of 85 people (Figure II-9) during the operational phase of the Tug program. Functional details of the management organization are found in subplan B.

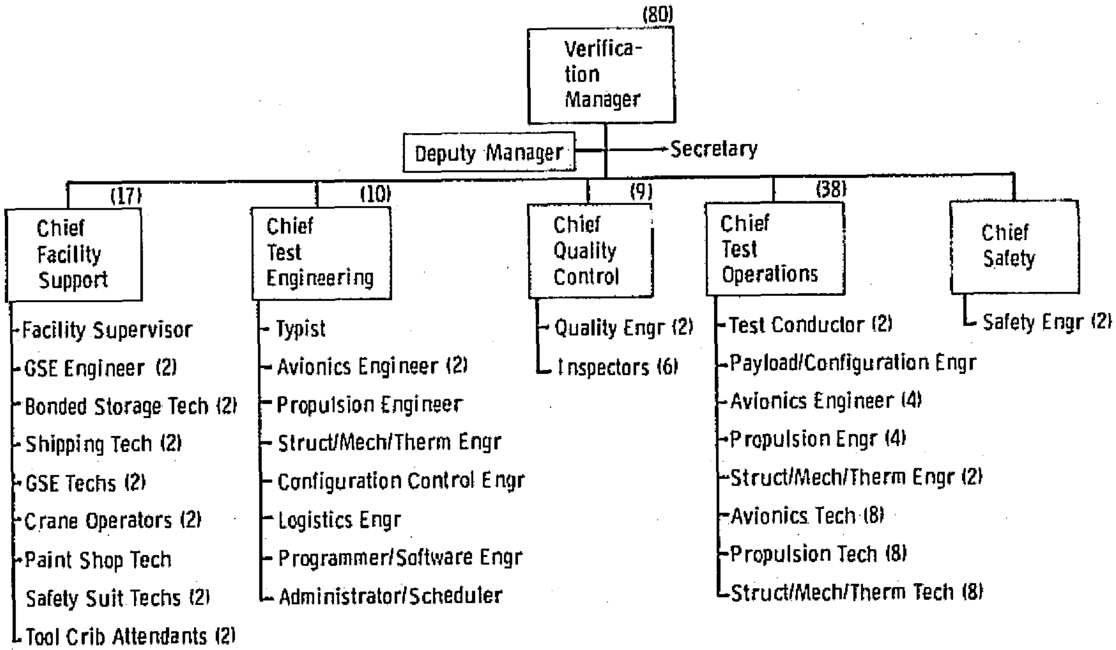


Figure II-7 ETR Launch Site Operations Crew Size

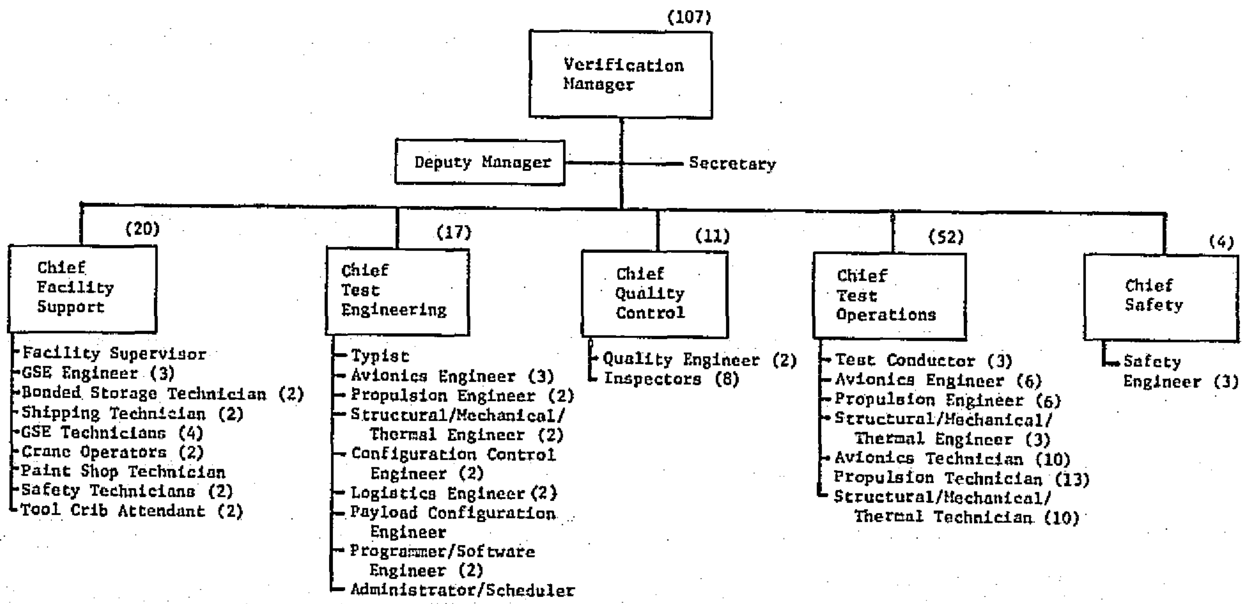


Figure II-8 ETR Crew Organization (with WTR Launch Capability)

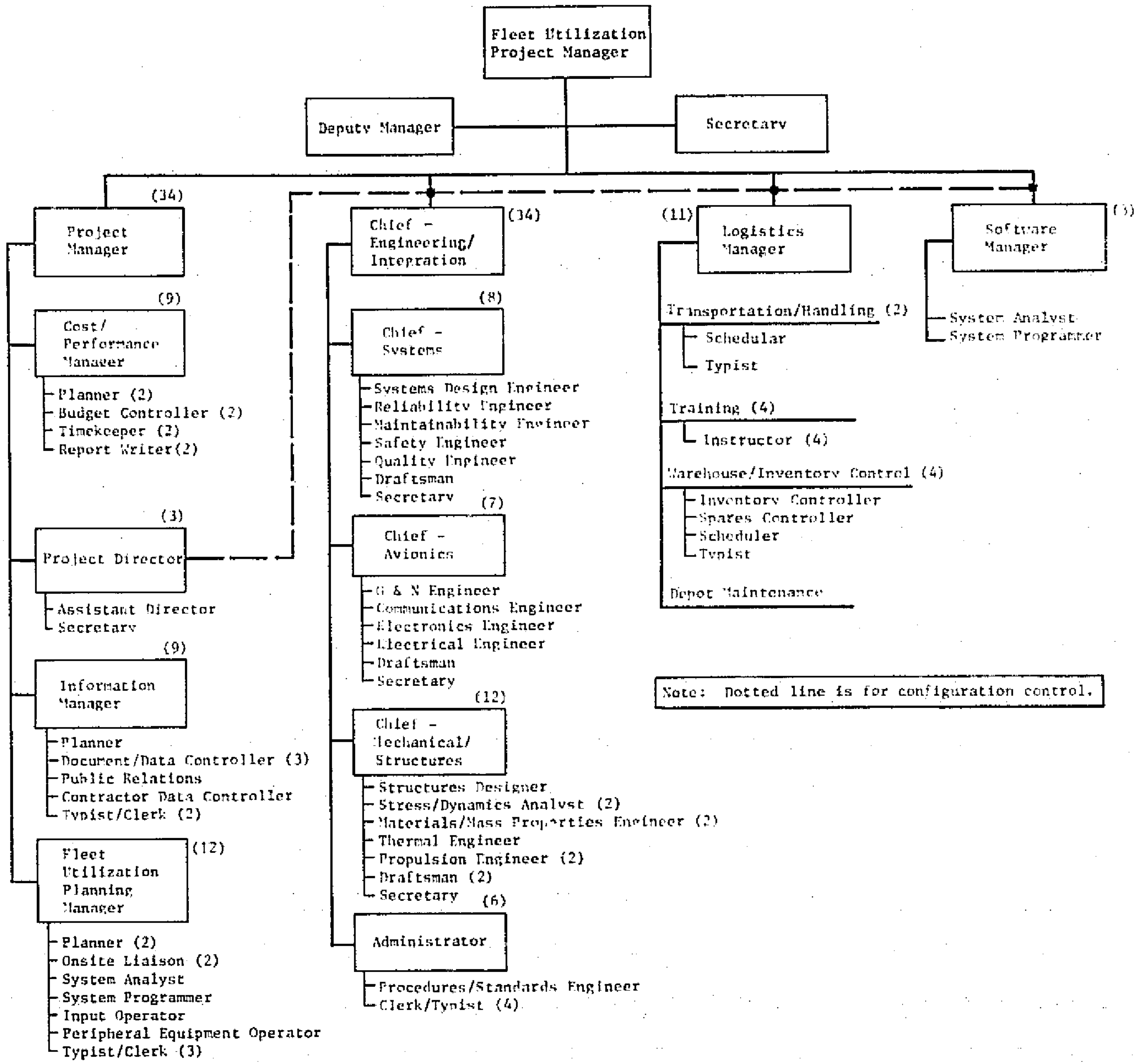


Figure II-9 Fleet Utilization Management Organization

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2.0 Spacecraft Crew Requirements

Payload integration will not require additional Tug personnel. Spacecraft supplied personnel will include technical representative(s) responsible for spacecraft status/test evaluation. Spacecraft personnel will also be required to handle the spacecraft before mate and, if required, operate spacecraft peculiar GSE.

3.0 Crew Phasing

Tug site activation can be divided into three distinct phases: (1) planning, design, and construction; (2) facility/GSE verification with a Tug Engineering Model; and (3) processing, checkout, and launch of the first flight article. Manpower staffing during the activation phase is based on the requirements of each phase resulting in a gradual build-up from a skeleton force to a full operational crew during engineering article checkout.

4.0 IUS-Tug Crew Commonality

Because of the basic system differences between IUS and the Tug it appears that separate refurbishment/checkout crews should be used for the IUS and Tug. As the IUS or Tug nears completion of the refurbish/checkout cycle the systems level stage operations tend to become more common.

Two areas of crew operations similarity are APS servicing and helium pressurant servicing. Since both stages have similar APS and helium pressure systems personnel would be certified to perform these operations on both the IUS and the Tug. Another area is the handling of the IUS and Tug when it is in the payload canister or the B-747 canister. The handling operations of the IUS and Tug after delivery to the pad and removal from the canister will be similar through installation in the Orbiter cargo bay. These handling operations could be done by a common crew certified to handle both stages.

Individual certification and skill certification (soldering, potting, etc) have some commonality that would apply to operations on either IUS or Tug. Since IUS usage is less than Tug usage during the transition period, the number of Tug certified personnel would be greater; also since only Tugs will be flown from WTR, the traveling launch crew needs to be certified for Tug only.

F. SAFETY REQUIREMENTS AND SUPPORT

1.0 Program Approach

Normal Tug ground operations include inherently hazardous operations that must be controlled and reduced to the lowest practial level consistent with program objectives, cost, and schedule.

Deviations from the normal processing flow must be anticipated during Tug fleet operations. The Tug normal operations safety philosophy must be to add energy sources, such as propellants, as late as mission requirements permit and to eliminate each energy source as soon as practical after the mission requirements for that energy is completed. The Tug contingency safety philosophy must be to provide for backout to a safe condition or, as a minimum, to limit the extent of catastrophic events.

2.0 Safety Management

Ground operations at any STS base will involve complex relationships between the STS, Tug, and various spacecraft organizations. The operations will be conducted on compressed schedules and involve close coordination, particularly for hazardous operations. Even at a minimum these conditions require considerable safety support planning to comply with the SSP safety policy.

The safety program developed by safety support planning will be documented in a Safety Plan. The plan will define the safety program elements in sufficient detail to provide interface with other contractors/agencies and provide assurances to the responsible Tug agency of policy compliance. The following elements, as a minimum, shall be included in Tug Operations Safety Plan(s).

2.1 Policy

This is the definition of the contractor's policy concerning the safety program, the responsibilities and authority of the safety organization, and management methods used in accident prevention.

2.2 Program Interfaces

This defines how the Tug safety program interfaces with the STS, spacecraft, and host base safety programs. Participation in Safety Working Groups or committees, data exchange, and transfer of responsibilities should be included.

2.3 System Safety

This defines the actions employed to identify and control hazards during Tug ground operations. Due to the magnitude of the Tug potential hazards, an in-depth analysis of each operational function will be required. The analysis will be based on final design of the Tug and interfacing facilities/GSE and identify the procedural constraints required to control residual hazards.

2.4 *Operating Procedures*

This is a definition of the requirements for operating procedures, identification of hazardous procedures, and the role of safety in the review/approval of procedures.

2.5 *Safety Monitoring*

The plan will include definition of the provisions for qualified safety personnel to monitor hazardous operations and the scope of authority of the safety monitor.

2.6 *Industrial Safety*

The plan will define the policies and procedures to be applied to the work areas that are similar to industrial plants. These procedures and controls will comply with the Occupational Safety and Health Act requirements. Safety training and motivation programs will also be defined.

2.7 *Accident Reporting*

The plan will define the procedures to be used in investigating and reporting all accidents/incidents. The procedures will include independent investigations, support to host base or agency investigations, and routine periodic accident/injury reports.

3.0 Design Safety

Implementation of the safety philosophy for design begins with the establishment of preliminary safety requirements. This has been accomplished for the Tug program by the Baseline Space Tug Requirements and Guidelines, MSFC 68M00039-1. These requirements may be refined and will become more comprehensive as a result of this and related studies. The safety requirements will continue to mature as the result of future studies and analyses.

Iterative system safety analyses performed in conjunction with design evolution provides for hazard identification and resolution. Hazards are eliminated or controlled by imposing existing or new criteria on the designs. Hazard elimination or control actions are guided by the following established hazard reduction precedence sequence:

3.1 Design for Minimum Hazard

The major goal throughout the design phase shall be to ensure inherent safety through the selection of appropriate design features as fail operational/fail safe combinations and appropriate safety factors. Hazards shall be eliminated by design where possible. Damage control, containment, and isolation of potential hazards shall be included in design considerations.

3.2 Safety Devices

Known hazards that cannot be eliminated through design selection shall be reduced to an acceptable level through the use of appropriate safety devices as part of the system, subsystem, or equipment.

3.3 Warning Devices

Where it is not possible to preclude the existence or occurrence of a known hazard, devices shall be employed for the timely detection of the condition and the generation of an adequate warning signal. Warning signals shall be designed to minimize the probability of wrong signals or of improper personnel reaction to the signal.

Further iterations of the analysis will confirm compliance with requirements and criteria to eliminate or control hazards or identify residual hazards. Residual critical hazards will be tracked and efforts continued toward reduction to an acceptable level.

4.0 Operational Safety

The prevention of accidental incidents is the primary goal of all operational safety efforts. Understanding of the potentially hazardous conditions is essential to establishing procedural constraints to accomplish that goal. The hazardous operations identified with the Space Tug program are common or similar to those of current aerospace programs, and the specific operational constraints are well known and accepted. Further assurance of safe operations is obtained by the training and certification of personnel for hazardous operations coupled with an appropriate amount of surveillance.

During the Site Activation Phase, the installation of equipment is governed by established industrial safety practices and the host base standards and regulations. The checkout of equipment and first Tug processing requires intensive safety effort to minimize accident/incident potentials. In addition to performing special one-time operations, the normal operating procedures will be validated and verified. These activities require special care in procedure review/approval as well as extensive safety monitoring.

The Space Tug Operational Phase and the IUS/Tug Transition Phase consist of the routine functions of final postmission safing, refurbishment, and launch preparations. The hazardous operations involved have been identified as vehicle handling, transfer of propellants and cryogenics, pressurization, and electrical power operations. For normal turnaround operations, it is considered neither essential nor practical to achieve an absolute safe (completely inert) vehicle status for refurbishment. Hazard levels must, however, be maintained at an acceptable level consistent with the operations to be performed to implement the normal operations safety philosophy.

Deviations from normal operations must be anticipated during fleet operations. Credible hazardous contingencies have been identified involving fluid leaks and handling damage. Complete safing, such as system flushing and purging, would be required to correct the damage or anomaly that caused the contingency. Implementation of the contingency safety philosophy requires detailed backout/emergency procedures for each credible contingency to be developed in future program phases.

Payload integration is part of both IUS and Tug operations. Accurate identification of potentially hazardous spacecraft systems and postmating operations would require a detailed examination of data on each spacecraft. General requirements have been identified based on the assumption that spacecraft designs will, as a minimum, comply with the Spacecraft Safety section of Baseline Space Tug Requirements and Guidelines, MSFC 68M00039-1. These requirements are that the spacecraft agency must identify all residual hazards and provide the necessary normal and backout procedures to the IUS/Tug processing agency.

The spacecraft agency will also be responsible for providing portable hazard monitoring equipment that may be required. Spacecraft that contain elements that generate hazardous conditions, such as pressures or temperatures, must be monitored and controlled. Portable hazard monitoring equipment will provide these functions during mated transportation and handling activities.

G. FLEET UTILIZATION AND IUS/TUG TO PAYLOAD INTEGRATION REQUIREMENTS

1.0 Fleet Utilization

Fleet utilization is concerned with fleet sizing, fleet management, resource requirements, and contingency definition/planning; it is an operational phase function with little or no applicablility in the other program phases with the exception that elements of fleet management are applicable to all phases of the program, e.g., project management, engineering, logistics, software development, planning.

1.1 Fleet Sizing

Fleet sizing consists of three factors: (1) total fleet size, (2) active fleet size, and (3) annual inventory requirements. The total fleet size requirements are based on the Tug and IUS traffic model (Table II-5); the number of flights expending a Tug (eight); the decision to make the IUS expendable or reusable; the number of flights a Tug (or reusable IUS) can make before it is "worn out" (baseline 20) and the IUS to Tug transition (none, 1 year transition or continuing IUS use through 1991).

Table II-5 Tug/IUS Traffic Model Used in the Study

Source	MMC Data	MSFC/MDAC Data			IUS Data from MSFC NASA/DOD Data from MMC Extrapolation for IUS Tug Data from MSFC/MDAC								
Configuration \ Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total
Expendable IUS - No Transition with Tug NASA - ETR Only DOD - ETR Only	9 8 1	16 11 5	14 5 9	17 10 7									56
Expendable IUS - 1 yr Transition with Tug NASA - ETR Only DOD - ETR Only	9 8 1	16 11 5	14 5 9	17 10 7	7 5 2								63
Expendable IUS - IUS Used Through 1991 NASA - ETR Only DOD - ETR Only	9 8 1	16 11 5	14 5 9	17 10 7	7 5 2	4 2 2	3 1 2	1 0 1	1 0 1	2 0 2	1 0 1	1 0 1	76
Tug - No IUS Transition NASA - ETR/WTR DOD - ETR Only					19 13/2 4	22 11/1 10	24 15/2 7	18 12/1 5	18 11/1 6	16 11/1 4	26 17/2 7	22 14/1 7	165
Tug - 1-Yr IUS Transition					13	22	24	18	18	16	26	22	159
Tug - Using IUS through 1991					13	19	23	18	18	16	26	22	155

The active fleet size is determined by the ground turnaround time, annual launch rate and the number of working days between launch centers; the inventory requirements are a combination of the active fleet size requirements and the expended Tug rate.

The active fleet size and inventory requirements for the Tug and reusable IUS are depicted in Figures II-10, II-11 and II-12.

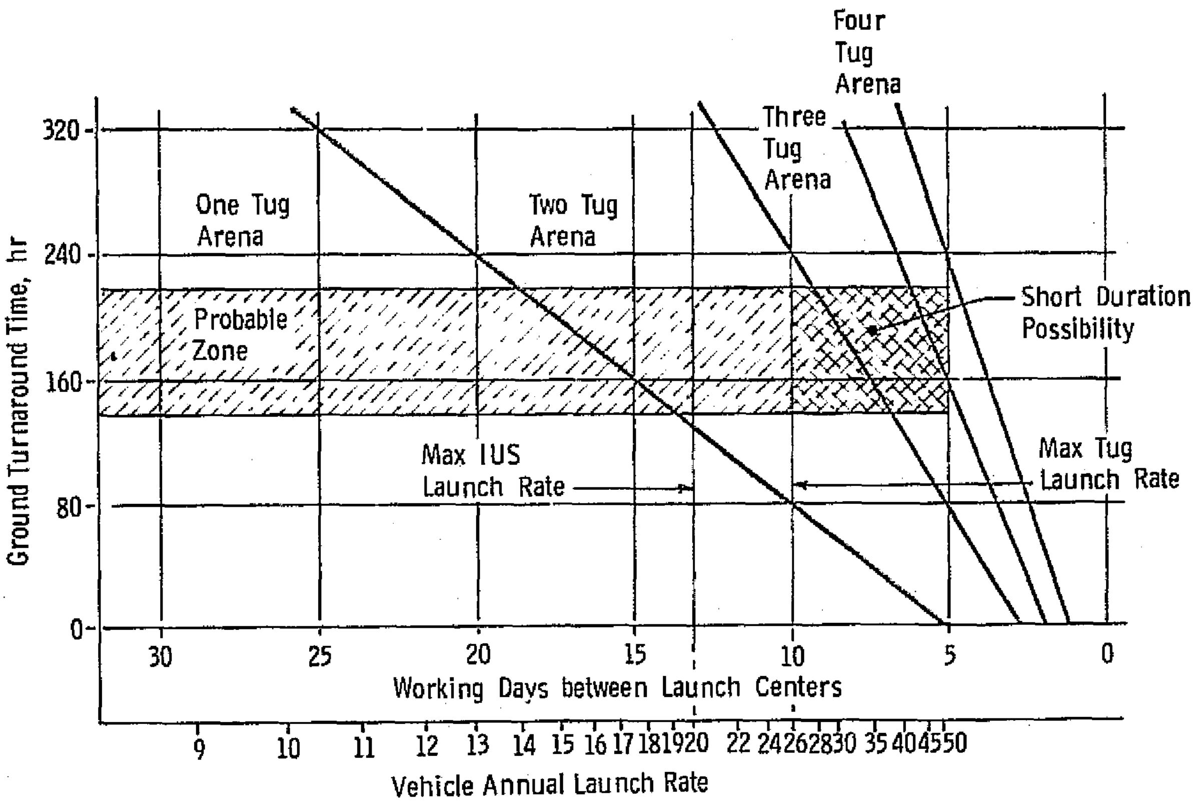

Figure II-10
Vehicle Active Fleet Size - Tug or IUS - vs Turnaround Time, Launch Rate, Launch Centers

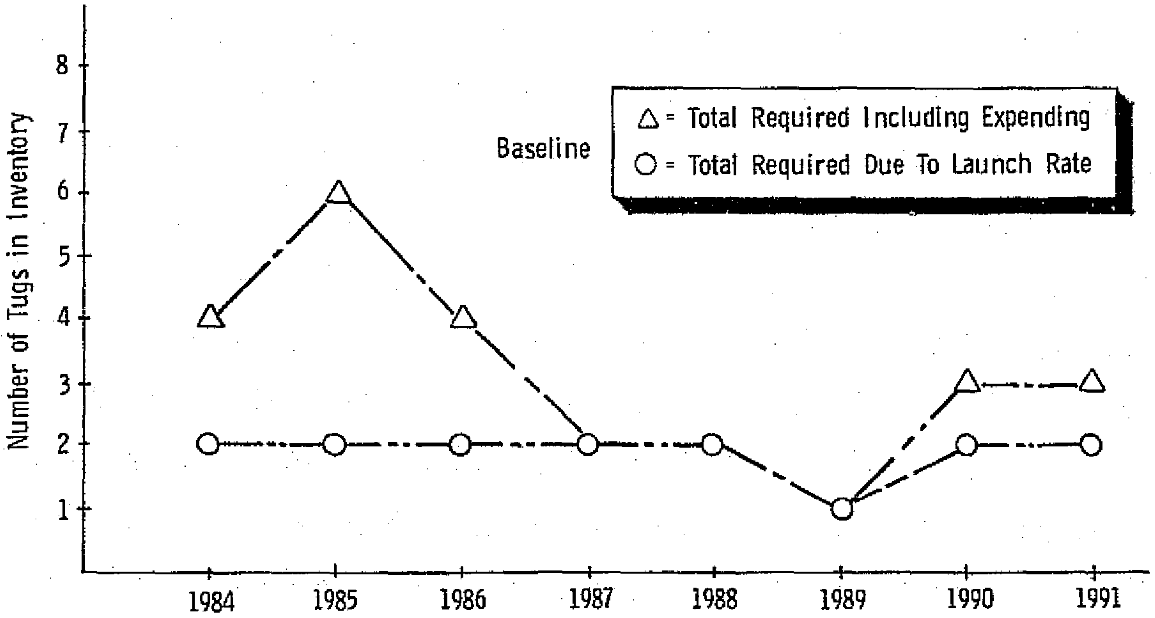

Figure II-11 Minimum Annual Tug Inventory Requirements

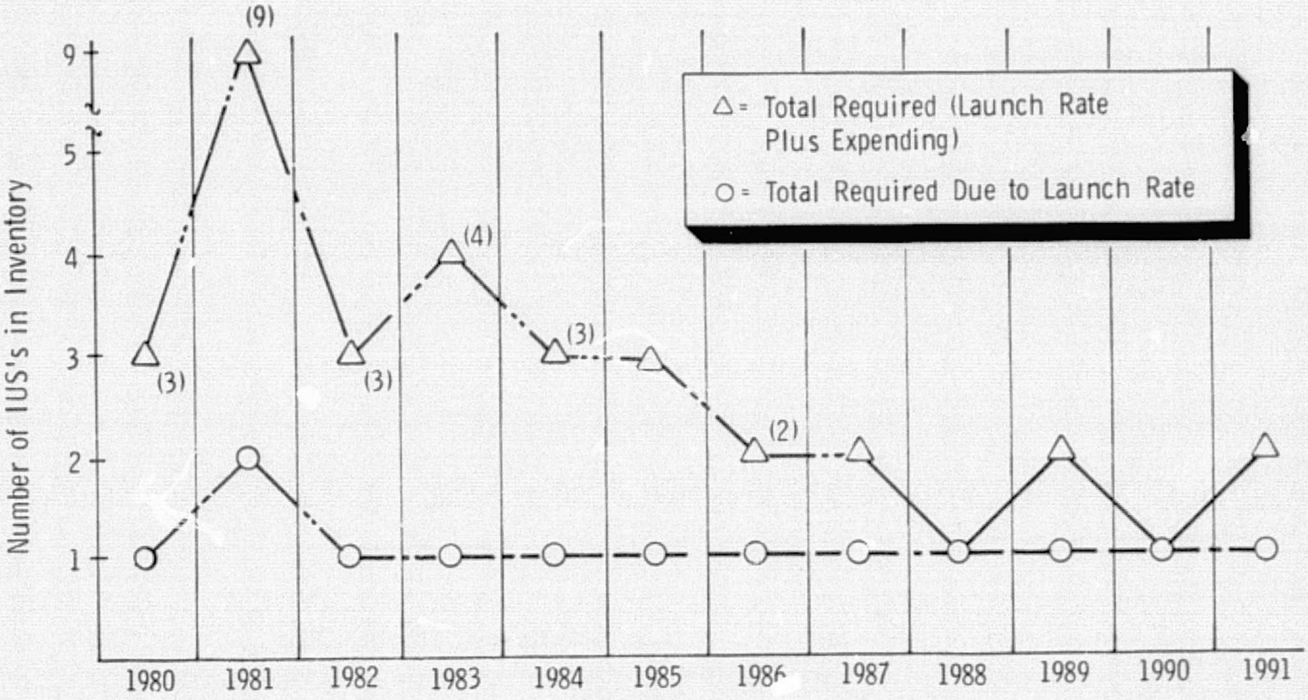

Figure II-12 Minimum Annual Reusable IUS Inventory Requirements

Figure II-13 depicts the formula used to determine total fleet size requirements for Tug and reusable IUS. The expendable IUS total fleet size requirement is simply the number of flights.

Total Reusable IUSs required = 15 to 18 (no transition)
= 17 to 20 (1 yr transition)
= 23 to 27 (IUS used through 1991)

Total Tugs required = 13 to 16 (no IUS transition)
= 13 to 15 (with IUS used through 1991)

1.2 Fleet Management

Fleet management for the Tug ground and flight operations program provides a diverse set of services. These services include performance management, configuration management, data management, quality assurance and safety, sustaining engineering, logistics, interface control, mission planning, flight planning, Tug fleet utilization planning, and transportation/handling planning. To provide effective fleet management visibility and control, adequate program control systems must be implemented. Tug man/machine relationship illustrated in Figure II-14 is the approach used where the computer can most effectively generate the data needed for man to make the decisions.

$$\text{Total Tugs Required} = \text{Total Number of Expendable Tug Flights} + \left[\frac{\text{Total Number of All Tug Flights} - \text{Total Number of Flights by Tugs Being Expended}}{\text{Maximum Number of Flights per Tug}}\right] + \text{Unreliability Losses}$$

Note: The formula is the same for Reusable IUS, Substitute IUS, and IUS data.

Figure II-13
Basic Formula for Determining Numbers of Tugs and IUSs Required

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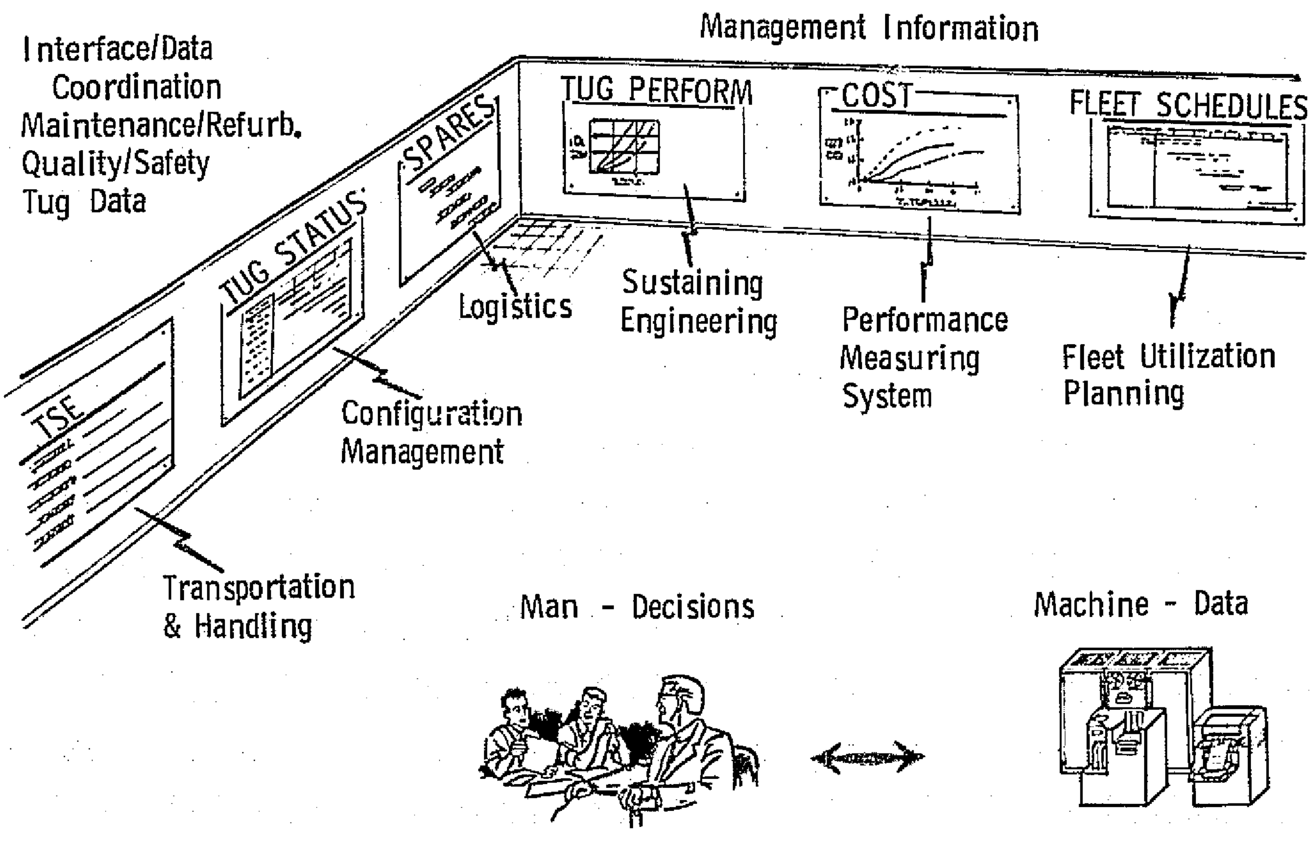

Figure II-14 Fleet Management

The performance management system includes planning and work authorization, cost per flight, and a Performance Measuring System (PMS). This system is adapted from the system that is currently in operation at the Orlando division of Martin Marietta Corporation, has been demonstrated, and is being implemented on the External Tank project after an extensive evaluation of various PMSs. For the latter system, the key performance parameter is cost per flight for a large number of tanks, which is analogous to cost per flight for a large number of Tug launches.

A machine assisted Tug fleet utilization system is a management tool that is necessitated by the high rate of missions that must be accommodated by the Tug fleet over an extended period of time. The system must provide utilization plans, planning aids, accommodate input of changes readily, produce firm utilization plans, and associated status data for different planning horizons (weeks, months, years). Additionally, the system will provide real time, near real time, and planning stage contingency management (analysis of alternatives and prompt implementation of the revised utilization plan).

The Configuration Management System driver is the provision for a comprehensive review of all baselines and changes by all cognizant parties, including interfaces. The basic system, a conventional implementation of MSFC Document MM8040.12 and standard Contractor Configuration Management Requirements, has proven to be effective. The challenge is to provide for a timely review and approval cycle.

The Information Management System (IMS) includes both data management and the Management Information Center (MIC). The dominant consideration is establishing adequate compatibility of this system with other Space Transportation System IMS. For data management, this can be accomplished by establishing a system that is compatible with the Space Shuttle program information control and retrieval system in terms of equipment and software for mechanized information submittal schedules and status, and information accessioning lists. The MICs should be planned on an austere basis to be cost effective. Compatible data and communications equipment are needed. Real time data can be limited to that required for the fleet utilization system.

Development of Logistics Operations planning as well as extensive technical documentation and training programs must be accomplished in collaboration with the Tug prime contractors and their suppliers. Centralized spares provisioning and control are required to be cost effective because of the large number of spare line replaceable units, the varying reorder lead times, and the complexity of maintaining all status data (including shelf life, life cycle data, configuration status, etc). Control of the logistics systems and techniques can best be accomplished at a location that facilitates the project management design and

sustaining engineering and configuration control support. The traditional transportation planning and coordination role of the project office is applicable.

Sustaining Engineering functionally includes all of the technical disciplines carried through from the DDT&E phase through the operational phase to integrate product improvement and changes as a result of user recommendations and/or operational experience. On-site and in-plant liaison are included, as is configuration control and system integration.

1.3 Resource Requirements

The resource requirements include facility, GSE, software, manpower and TSE, all of which are separately discussed in paragraphs II, B; II, C; II, E and II, I, and are only briefly included here from a fleet utilization standpoint.

Fleet utilization imposes requirements on the resources in terms of quantities required to meet the Tug traffic model (launch rate and location - ETR or WTR) requirements and contingencies. Facility requirements are summarized in Table II-6. The traffic model and contingencies impose no additional GSE requirements beyond those identified in paragraph II, B, 2.0 and Table II-2. In the software area, the traffic model imposes no additional requirements; however, for contingencies, redundancy in critical software is recommended as well as on-site validation capability for problem resolution. ETR manpower requirements are increased approximately 35% because of a WTR launch requirement. The manpower required to manage the fleet are approximately 75% of the ETR/WTR operating manpower requirements:

ETR/WTR manpower required = 114

Fleet management manpower required = 85

Total = 199

The launch rate and contingency requirements impact on TSE is shown in Table II-7.

1.4 Contingency Definition/Planning

Planning should be provided to alleviate contingencies should they occur. Categorically, the planning should include the following:

1) Provide "real time" spacecraft alternatives for contingencies involving or affecting the spacecraft, e.g., launch without the spacecraft, launch a degraded spacecraft, launch a buffer spacecraft.

Table II-6 Facility Requirements for the Space Tug - ETR and WTR

Source of Requirement / Facility	Stick-and-Ball Chart (Ref subplan A and Appendix C) Processing of a Single Tug		Tug Traffic Model	ETR Contingency Provision	WTR Requirements
	Function	**Requirement**			
Orbiter Processing Facility, OPF at ETR	Offload Payload from Orbiter	Existing OPF transfer Aisle	No Additional Requirements	None	None
	Demate Tug/Spacecraft and Remove COMSEC Equipment	Single Cell, Controlled Access, LPS Terminal Available, H_2 Burner, Tug Hazardous Vapor Detection.			
Tug Processing Facility, TPF at ETR	Receive, Inspect, Safe, Clean Tug.	Airlock, Controlled Access, LPS Terminal, 100K* Class Clean, Personnel Safety Provisions.	No Additional Requirements	None	None
	Tug Refurbish, Checkout, Spacecraft Mate/Integration	Single Cell - Controlled Access, 100K* Class Clean, Tempest Compatible, Parasitic Antenna, LPS Terminal, OIS Communication.	No Additional Requirements	Add a Second Cell for Backup - Provision Identical to Single Cell.	None - WTR Launched Tugs Will Be Checked and Refurbished in ETR-TPF
	Tug Adapter Maintenance and Checkout	Single Bay - 100K* Class Clean, OIS Communication, LPS Terminal	No Additional Requirements	Add a Second Bay for Backup - Provision Identical to Single Bay.	None - Adapter for WTR Launched Tugs Will Be Checked in ETR-TPF.
	Kick Stage Buildup and Checkout	Single Bay - 100K* Class Clean, OIS Communication, LPS Terminal	No Additional Requirements	None	None - Kick Stages not Required at WTR
	Load Storable Propellants	Single Bay, 100K* Class Clean, OIS Communication, LPS Terminal, Controlled Access, Personnel Safety Provisions	No Additional Requirements	None	Facility Requirements at WTR Are Identical to ETR
	Store Tug and Adapter	Not Required	The Tug Traffic Model and Contingency Provisions Require Storage of Up to Four Tugs and Two Adapters in a Temperature and Humidity Controlled Environment.		None - No Storage of Tugs and Adapters Is Required at WTR
	Store Refurbishment Support Hardware	Temperature and Humidity Controlled, Storage Racks, Bins, and Shelves.	No Additional Requirements	None	None - No Refurbishment Accomplished at WTR.
	Subsystem Overhaul Refurbish, Maintenance and Checkout Areas	Controlled Access, 100K* Class Clean, LPS Terminals, Bench Calibration, Optical Alignment Platform.	No Additional Requirements	None	None - No Subsystem Work Done at WTR
	Load Tug and Spacecraft into Payload Canister	100K Class Clean Area, Controlled Access, OIS Communication	No Additional Requirements	None	WTR Requirements Identical to ETR Requirements
Payload Changeout Room, PCR at ETR (and Launch Complex)	Payload Transfer to Orbiter Bay	100K Class Clean Room, LPS Terminal, Device for Handling Tug and Installing it Into Orbiter Bay (Vertical), Controlled Access, Tempest Compatible.	No Additional Requirements	Provide a Second PCR (and Launch Complex) Provide capability In Both PCRs to Changeout Entire Payload (Tug and Spacecraft), Spacecraft Only or Tug Only and Tug/Spacecraft Mate and Integration.	No Additional Requirements - ETR, Contingency Provisions Not Required
Launch Complex at ETR	Load Propellants and Pressurants	LH_2, LO_2, GHe Transfer and Vent Systems	No Additional Requirements	Provide a Second Launch Complex to Backup the First at ETR.	No Additional Requirements - No Backup Launch Pad Required
Orbiter Landing Field - OLF	No Tug Requirements				

*100K is baseline, factory clean is recommended.

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Table II-7 Tug Transportation Support Equipment (TSE) Requirements

Equipment Source	Item	TSE Location Requirements								Qty for Single Tug	Launch Rate or Contin-gency Qty	Total Qty
		Between KSC & WTR		Between MFGR & KSC		Between OLF & KSC		Onsite KSC	Onsite WTR			
		KSC	WTR	MFGR	KSC	OLF	KSC					
Motor Pool or Contractor	Prime Mover	X	X	X	X	X	X	X	X	2	3	5
TSE/GFE*	Transporter, Canister	X	X	X	X	X	X	X	X	2	3	5
TSE/GFE*	Payload Canister	X		X		X		X	X	1	2	3
Facility and Contractor	Overhead Crane	X	X	X	X		X	X	X	3	0	3
GSE	Hoisting Sling Kit - ID No. H-018	X	X	X	X	X		X	X	3	0	3
TSE/GFE*	Mate/Demate Fixture (MDF) and Support Kit	X	X		X	X	X	X	X	2	0	2
TSE/GFE*	747 Aircraft	X		X		X				1	0	1
TSE/GFE* or Contractor	Mobile Crane			X		X				4	2	6
TSE/GFE*	Storage Dolly					X				3	0	3
TSE/GFE*	Canister/747 Attach Kit	X		X		X				2	0	2
GSE	Transportation Instrumentation Kit - ID No. H-023	X		X		X		X	X	2	0	2
GSE	Tank Breather Set - ID No. H-020	X		X		X		X	X	2	3	5
GSE	LH_2 Tank Dome Cover - ID No. H-019	X		X		X		X	X	2	3	5
GSE	Tug Tie Down Kit - ID No. H-022	X		X		X		X	X	2	0	2
TSE/GFE*	Canister to 747 Aircraft Attach Kit	X		X		X		X	X	2	0	2

*TSE/GFE - Shuttle and/or Payload Provided - Multiuse-Equipment

2) Provide flexibility in system design to accommodate launch date variations. Initial design flexibility can alleviate or eliminate several contingent situations. Provisions should include additional Tug checkout cell in the TPF, additional GSE quantities for all items with greater than 30% usage per Tug processing cycle, increase length of work week.

3) Provide sufficient redundancy in system design to prevent critical single failure point (SFP). Functional redundancy should be provided in design of all facility commodity and utility systems, as well as critical GSE items. Every item shall be subject to analysis and every critical SFP in the design shall be justified to the project and/or program office.

4) Provide a backup Tug and backup kick stages in the active fleet. These will preclude major impacts to the schedule without increasing the total fleet size requirement.

5) Provide a flexible schedule and control system. The Tug fleet utilization system (paragraph 1.2) must be flexible enough to aid in contingency assessment and decision selection of alternative course of action.

2.0 IUS/Tug to Payload Integration

IUS/Tug to payload integration involves identifying support and interface requirements for IUS/Tug to payload accommodations during the mission planning era. These include payload interface requirements, operational resource identification and allocation, handling and safety procedures, integrated testing and checkout requirements, simulation and/or interface verification requirements, and data requirements.

The scope of IUS/Tug to payload integration includes the necessary planning and preparation before hardware arrival at KSC, and all activities from arrival of the flight hardware and ground support equipment (GSE) through launch. This planning and preparation includes those activities for Tug/spacecraft mating and integrated checkout of the Tug/spacecraft and integrated checkout with the Orbiter. It also includes the unique integration and operations requirements of multiple payloads, such as on-site/off-site and on-line/off-line integration.

Special emphasis was placed on the generation of a Tug User's Planning Guide Outline to provide data essential for advance mission planning and spacecraft conceptual design. The outline was oriented to those areas of user interest and needs in terms of Tug/spacecraft hardware interfaces, environments, available services, mission capabilities, spacecraft integration, and an overview to familiarize new users with the Shuttle/Tug Space Transportation System.

The details of the integration analysis can be found in subplan C. The significant conclusions follow.

1) Multiple payload integration should be performed off-line before interface verification with the Tug.

2) Payload to Orbiter Level I integration should be accomplished in the TPF.

3) All GSE for solo spacecraft processing before Tug/spacecraft mate is the responsibility of the spacecraft owner, as is any spacecraft-unique GSE.

4) Any cleanliness protection greater than 100K clean must be provided by the spacecraft owner.

5) Spacecraft transportation and handling before Tug/spacecraft mate (or subsequent to demating) is the responsibility of the spacecraft owner, after mating the primary responsibility belongs to the IUS/Tug processing agency.

6) Spacecraft owner's manpower must be prepared to work a 5-day, 2-shift per day operation after Tug/spacecraft mate.

7) Spacecraft design will meet MSFC 68M00029-1.

8) Spacecraft owner will report all residual spacecraft hazards to the IUS/Tug processing agency before mating.

9) The spacecraft owner will provide any portable hazard monitoring equipment the spacecraft may require.

10) Spacecraft elements that generate hazardous conditions on the spacecraft must be monitored and controlled.

11) Integration will include analysis of loads, trajectory, mass properties, contamination, environments, missions, safety to ensure compatibility. The analysis should precede on-site activities.

12) Spacecraft simulators will be used for site activation and verification.

13) Considerations of standard connector mate/demate, maintenance access, and general implementation of the LRU concept should be reflected in the spacecraft design.

14) A Tug User's Guide will be provided to guide users through all phases from spacecraft conception, development through launch processing, launch and recovery operations.

15) The Tug User's Guide will provide the detail of what is expected of the user.

16) The Tug User's Guide should be a compliance document for all users, e.g.; it should be contractually imposed.

17) The Tug User's Guide will contain four basic elements: (1) hard compliances imposed by the Tug, (2) negotiable variable accommodations provided by Tug, (3) definition of specific and/or split responsibilities, (4) agreements between Tug and spacecraft agencies unique to each flight/mission.

18) The Tug User's Guide will: (1) identify the functional and physical characteristics of the Tug, (2) control changes to those characteristics, (3) provide a means for the user to implement his mission objective.

H. SITE ACTIVATION AND VERIFICATION

1.0 Site Activation Concept Selection and Approach

Before the A&E activities can start the basic processing philosophy and facility selection must be determined. The processing philosophy, i.e., Tug processing clean or unclean, affects facility selection.

1.1 Class 100,000 Clean Tug Processing

Figure II-2 provides the advantages and disadvantages of Class 100,000 clean Tug processing in the two most promising KSC facilities, SAEF-1 and VAB Low Bay. Figure II-15 depicts the flight hardware flow for this approach. The SAEF-1 could not be used as a common TPF (IUS and Tug processing) because of interference between on-going IUS operations and construction activities during Tug site activation. It is recommended that IUS and NASA and NN/D spacecraft be done in the IUS facility because of space limitations in the SAEF-1.

1.2 Factory Clean Tug Processing

Figure II-3 shows the advantages and disadvantages of factory clean Tug processing in the same facilities considered above. Figure II-16 depicts the flight hardware flow for this approach. A clean area or room would be provided in each refurbish/checkout cell to provide a Class 100,000 clean environment for spacecraft operations. Cleanliness over Class 100,000 would require local protection (bagging) for components on spacecraft. If desired the VAB Low Bay could be used as a common TPF, however, a commonality study (Section 4.1) shows this to be of little advantage.

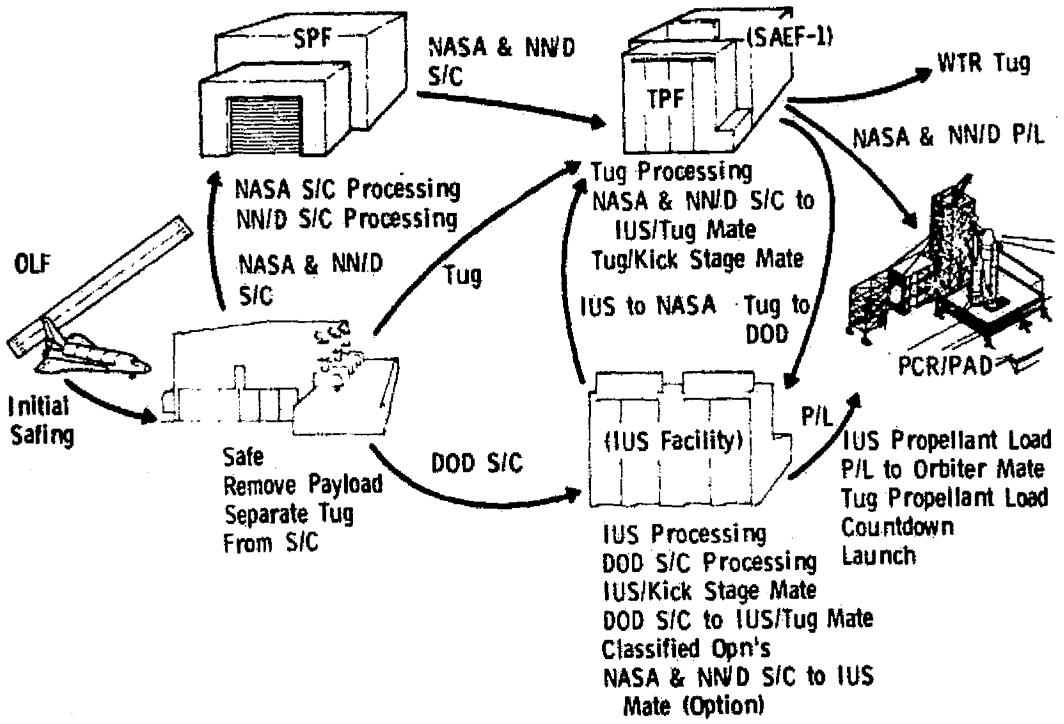

Figure II-15 Class 100K Clean Tug Processing

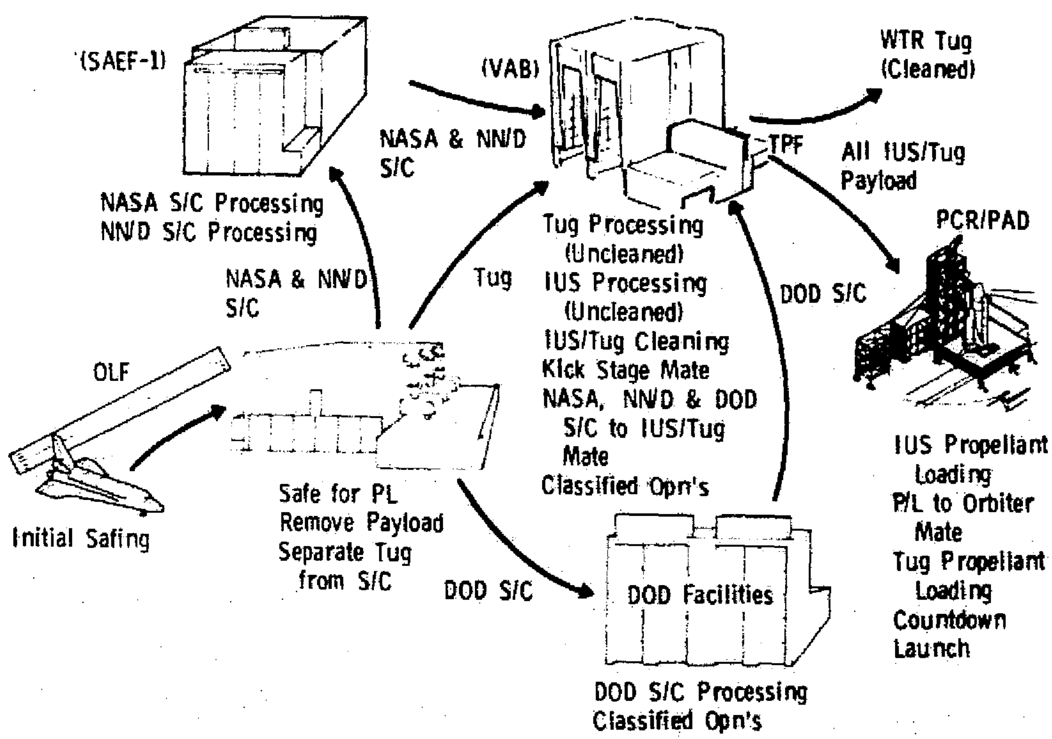

Figure II-16 Factory Clean Tug Processing

1.3 Conclusion and Recommendations

Figure II-17 lists the conclusions and recommendations reached. Since the recommendation is to process the Tug in a factory clean environment (Addendum 10), such an activity in the SAEF-1 would be a poor use of KSC resources. Therefore, the VAB Low Bay is the recommended facility for space Tug processing.

Conclusions

- Little Commonality IUS/Tug
- Advantages To Controlled Factory Environment Processing
- For Clean Processing
  - SAEF-1 Is Suitable for Tug
  - Process IUS in Separate Facility
- For Controlled Environment Processing
  - VAB Low Bay Is Suitable
  - IUS & Tug Can Be Processed In Common Facility

Recommendations

- Process The Tug In A Controlled Factory Environment In The VAB Low Bay
- Use SAEF-1 For S/C Processing
- IUS Can Be Processed In The VAB or Separate Facilities

Figure II-17 Commonality Conclusions and Recommendations

2.0 Design and Construction

To accomplish IOC in December 1983, the selected Tug facility must be available for modification to a TPF in December 1980. Supporting Tug facility modification availability dates are: OPF, April 1981; and PCR/PAD, February 1981. Figure II-18 depicts the major milestones to accomplish a timely construction phase of Tug Launch Site Activation Program. Figure II-19 provides the construction phase schedule. This phase ends when the installed GSE checkout program is completed.

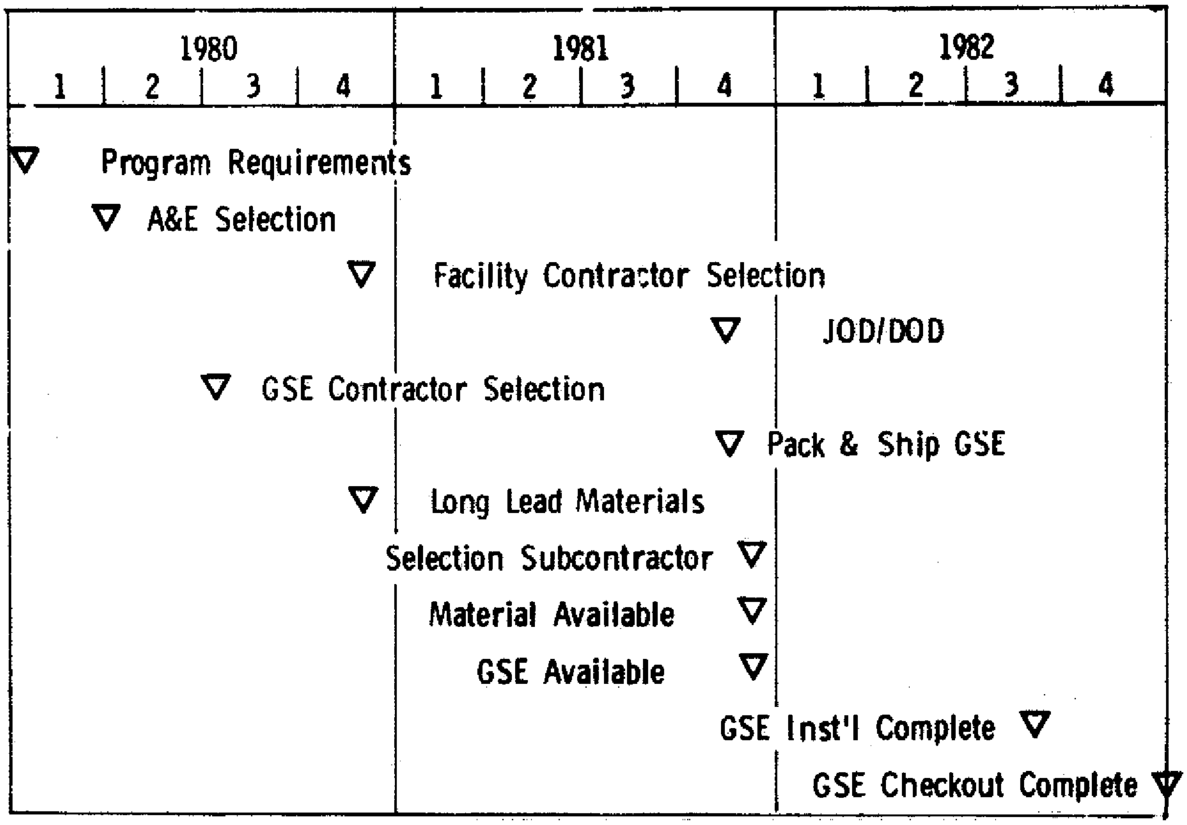

Figure II-18 Construction Phase Milestones

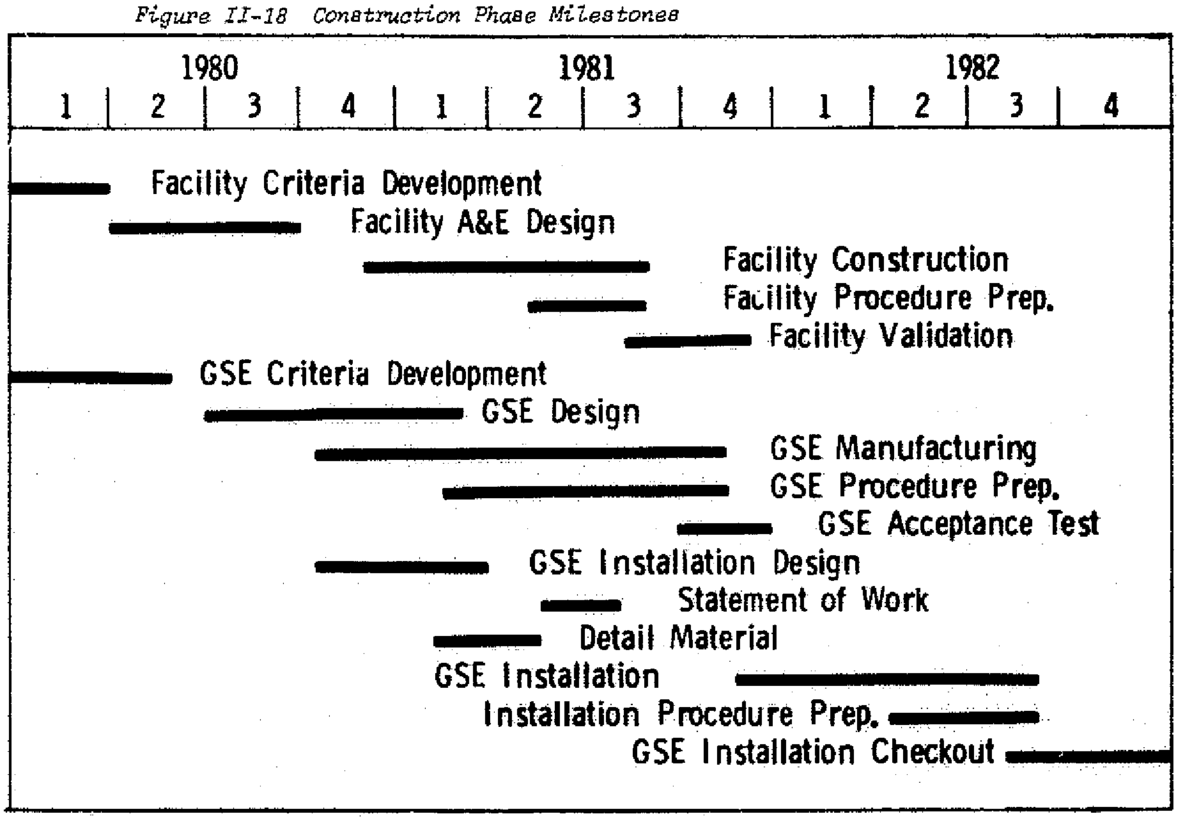

Figure II-19 Construction Phase Schedule

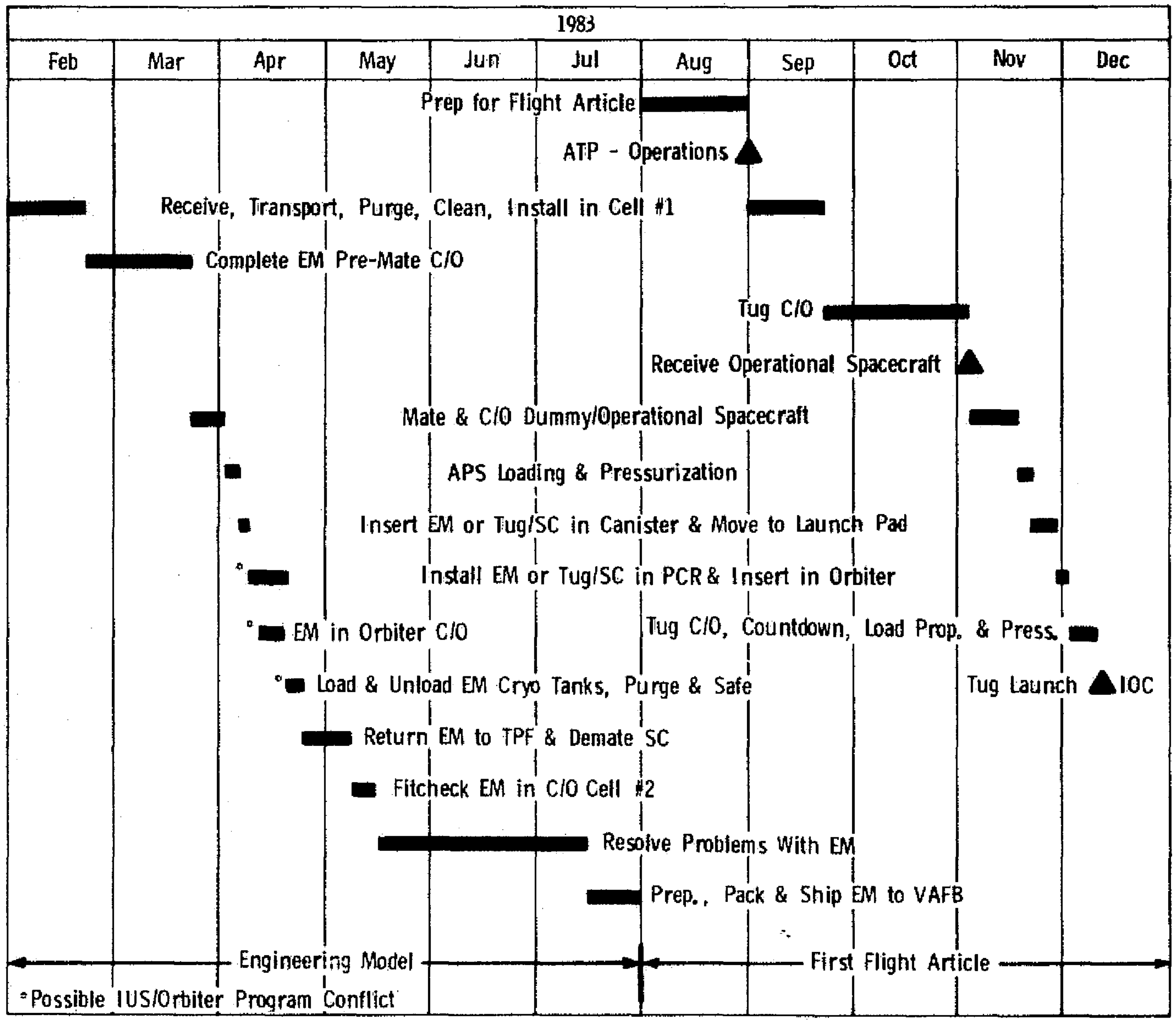

Figure II-20 Engineering Model and First Flight Article Schedule

3.0 Activation/Verification

3.1 Engineering Model

An engineering model will be used to verify the Tug processing facilities. This model would be an existing Tug qualification article or high fidelity development article refurbished as required to perform the site verification function. This model will also be used to refine operational procedures and train operating crews. The model will be undergoing processing at KSC starting in February through July 1983 when it is shipped with an activation crew to WTR for WTR site activation/verification. Figure II-20 provides the schedule for the engineering model flow through KSC facilities. After use in WTR site activation, the model is returned to KSC in November for use as a training aid.

3.2 First Flight Article (FFA)

The FFA is scheduled to be launched in December 1983. To meet this schedule the FFA must be available on site in early September 1983. The refined operational procedures will be updated and the Tug operational crew will be certified using this article. The schedule for this article is also shown in Figure II-20.

3.3 Summary

Assuming the first Tug launch to be December 1983 and a Tug launch site modification "go-ahead" in January 1980, the critical dates or milestones for KSC activities are those shown in Table II-8.

4.0 IUS to Tug Transition

4.1 Commonality

The commonality between the IUS and the Tug from the standpoint of checkout facilities and GSE is summarized in Figure II-4. The figure shows there is little commonality between these two stages. A summary of commonalities on other considerations is shown in Figure II-21; again, the result is that there is not much commonality between the stages. Figure II-22 summarizes the commonality issue between the IUS and the Tug, and provides a recommendation to be considered in the concept and design phase.

Table II-8 Critical Milestones

Sites	
TPF Available for Modification	December 1980
OPF Available for Modification	April 1981
PCR/PAD Available for Modification	February 1981
TPF Ready for Engineering Model Checkout	February 1983
PCR/PAD Ready for Engineering Model Checkout	April 1983
OPF Ready for Engineering Model Checkout	June 1983
Equipment	
Engineering Model at KSC	February 1983
Dummy S/C and Kick Stage at KSC	February 1983
Canister/Transporter Available	April 1983
Orbiter Available on Pad for Engineering Model C/O	April 1983
First Flight Tug on Site	September 1983
S/C and Kick Stage Ready for Mate	November 1983

4.2 Transition

Considering the recommendation to process the Tug in a factory-clean environment in the VAB Low Bay, and the current SAMSO ground rule of clean IUS processing, there is little involved in the transition from IUS to Tug. The baselined IUS is an expendable stage, while the Tug is a reusable stage. Because of lack of commonality in facilities and GSE, transition will be more an activation of new equipment. There is commonality in the area of site-to-site transportation requirements. These are basically handling requirements and pose little problem. Crew size will be a factor because the lack of commonality and similarity will require two crews, IUS and Tug, during the transition period.

The general safety requirements for the IUS and Tug are similar because both stages will be involved in hazardous ground operation. Hardware and system differences will require unique safety requirements for each stage so that procedural constraints for hazard control must be incorporated into definitive operating procedures, which will be stage-peculiar. Transition from IUS safety requirements to Tug safety requirements should not be a problem.

Item	Tug	IUS	Commonality
• Schedules	IOC Dec 1983, Variable Launch Rate Thru 1991	IOC 1980, Heavy Traffic to 1984 Transition, Sustaining Low Level Traffic 1991	Little Compatibility. Tug Facility Mods and Activation During Heavy IUS Traffic Period
• Software, Ground Checkout	LPS Unique Software	Van Mounted "Cage" Type System	No Commonality
• Crew Considerations			
Crew Skills	Cryogenic/Avionics	Hypergolic/Avionics	Some Commonality in Avionics Skills
Crew Training	Individual and Crew Certification for Tug Unique Systems	Individual and Crew Certification for IUS Unique Systems	Little Crew Certification Commonality. Some Common Individual Certification
• Safety	Cryogenics, Hydrazine (APS), Fuel Cell, Handling	Hypergolics, Hydrazine (APS), Batteries, Pyrotechnics, Handling	Common Safety Requirements for Handling and APS Servicing
• Fleet Utilization/Management Concepts	Moderate Active and Total Fleet, Significant Spares Inventory 7-8 Years Operation. NASA "Paper" System	Small Active/Total Fleet Small Spares Inventory, Heavy Traffic 3-4 Years Only. DOD "Paper" System	Some Common Systems Possible

Figure II-21 Commonality Assessment Considerations

LITTLE COMMONALITY IN:

Processing Facility Requirements
Checkout Equipment Concepts
Servicing Equipment
Crew Considerations
Schedules
Software

SOME COMMONALITY IN SUCH THINGS AS:

Safety Considerations
Fleet Utilization Management
Support Shops
Kick Stage Processing
Storage/Warehousing

CONCLUSIONS:

Little Apparent Advantage To A Common IUS/Tug Processing Facility

RECOMMENDATIONS:

Don't "Force Fit" IUS Into Tug Processing Facility

Consider Common Support Shops, Storage/Warehousing, Kick Stage Processing, Management Systems

Figure II-22 Commonality Assessment Conclusions and Recommendations

The IUS will use IUS-unique GSE for checkout while the Tug will use the LPS. Most spacecraft software will be modular with the test sequences dictating which modules will be used. Therefore, it appears that during transition every possible combination of old and new software will exist. The LPS software contractor's role will be to standardize many different requests and consciously maintain as much software commonality as possible. The transition phase from IUS to Tug is not seen as a big step function having undue software effects.

The various elements of logistics support will vary widely in application between Tug and IUS, based primarily on major differences in size, component configuration, and the reusability aspects of Tug versus IUS. The logistics management function will be concerned with entirely different approaches to such areas as spares procurement and maintenance planning based on a reusable Tug and an expandable IUS. Maintenance and repair activities differ considerably because of configuration differences. Training, for the most part, will be peculiar to each stage. The operational technical documentation requirements are seen as unique to each stage. In the transportation and handling area, the piggyback cargo canister concept can be used for IUS and Tug with all the resulting commonality benefits. In the final analysis the best logistics approach for IUS and Tug is one of separate programs and separate control with shared commonality as appropriate.

The configuration control approaches used for IUS payload will be directly applicable to Tug payloads. Therefore, little transition impact will be noticed in this area. There will be some change in functions as the engineering and procuring agencies change from IUS to Tug, however, with adequate preplanning a smooth transition can be effected.

I. GROUND SOFTWARE DEVELOPMENT

1.0 Program Requirements

Software for all major systems fall into four classification: (1) operating systems; (2) application programs; (3) language processors; and, (4) support programs. Software requirements data sheets have been prepared for each operational step and include software in each of the four classifications. These data sheets are shown in Appendix D.

During Tug operations software will be either nonrecurring or recurring. The nonrecurring software (operating systems, language processors, and most support programs) will have been developed during the activation phase. This software is not expected to change because of the fixed systems it services. The nonrecurring software will normally remain fixed while the recurring software is integrated with it and worked around it.

The recurring software (application programs and some support programs) results from changing components, systems, methods, payloads, and requirements. As hardware changes, its software waterfalls through element test, subsystem test, combined systems tests, integrated tests, and countdown. Optimization of a subsystem or system affects the software in the same manner as hardware or LRU changes.

Assisting operational software preparation are the support programs. These programs aid preparation, provide debugging support and simulations, and provide software validation routines for verification and limited validation. These support programs are expected to be relatively fixed, requiring no continuing software modifications. In the operational phase, changes to the software are expected to be minor unless there is a technological breakthrough that materially affects programming in general.

2.0 Management Implementation

Software integration is expected to be more of a problem early in the Tug program rather than later when the software modules and working procedures have been developed, refined and validated during refurbish/checkout operations. Two ground software problems have been identified that can potentially affect fleet utilization. They are software accuracy and software lateness.

The solution to software accuracy is to provide high fidelity validation hardware during software development. One solution to late software or software "no show" is to provide experienced and talented programmers on the project. The best approach to avoid either problem is strict adherence to an orderly software development process which is scheduled to comply with launch site operational requirements. This process should be under close surveillance by the LPS contractor and NASA to assure that software will be available when required at the launch site.

3.0 Spacecraft Impact

Tug software for payload integration requires input from the spacecraft contractor. The spacecraft contractor may request from the Tug contractor initiating functions and status of the Tug as inputs. Operational outputs from the spacecraft that may require Tug software processing are spacecraft health monitors and status, C&W, and self check information. The spacecraft may also levy software requirements on the Tug in the form of orbital functions, i.e., altitude, velocities, spin, separation restriction, deployment sequence, final check, etc. The information exchange is a two-way operation.

The situation of a new payload entering the ground processing cycle every few days makes efficient integration mandatory. Standardization of services and software will help, however, our experience with spacecraft and experiments has shown that software requests will not be orderly, the reaction time requirements will be shorter, the requests will not be standard, and changes will be frequent. The bulk of the nonrecurring software preparation during the operational phase is expected to be centered around spacecraft integration. Eventually, enough spacecraft will be processed so that software development will consist of modifying existing routines. This will aid in the payload software integration process.

4.0 Software Development and Validation

By the time site activation occurs and the engineering model of the Tug arrives at KSC for site validation some software will have been developed, verified, and used during the KSC program. The Tug software program will be a cooperative effort between the Tug contractor, NASA, and the LPS contractor. The desired objective will be to develop the software early and bring it to the launch site integrated and validated.

Validation does require element hardware to eliminate large impacts at the launch site. Partial validation could take place at the Tug contractor with a partial CCMS and telephone links to a development CDS. The primary activation problems should then be narrowed to hardware problems, once the software has been developed. Figure II-23 depicts the software development-validation cycle. State-of-the-art software sophistication and time allocated by current shuttle program schedules for software development lead to the conclusion that software should not be a large factor during site activation.

5.0 IUS Interface

Current IUS planning is developing without direction to use the LPS and with the goal to reduce hardware development costs. Therefore, it is apparent that the IUS will arrive at the launch site with its own checkout GSE and software. Spacecraft are expected to have even more variable GSE and software throughout the early part of the Shuttle program. The Tug will be designed to use the capabilities of the LPS to the maximum extent throughout the refurbish/checkout/launch cycle. Wherever the spacecraft is mated and tested with IUS, kick stage or Tug, the combined testing will marry diverse elements, and eventually the entire combination will reach the launch pad and Orbiter. At the pad, from T-4 to liftoff, LPS will be used. Prior to T-4, a combination of dedicated GSE, airborne computer, and LPS are possible. In all cases software will probably be modular in form, i.e., IUS, Tug, kick stage, and spacecraft.

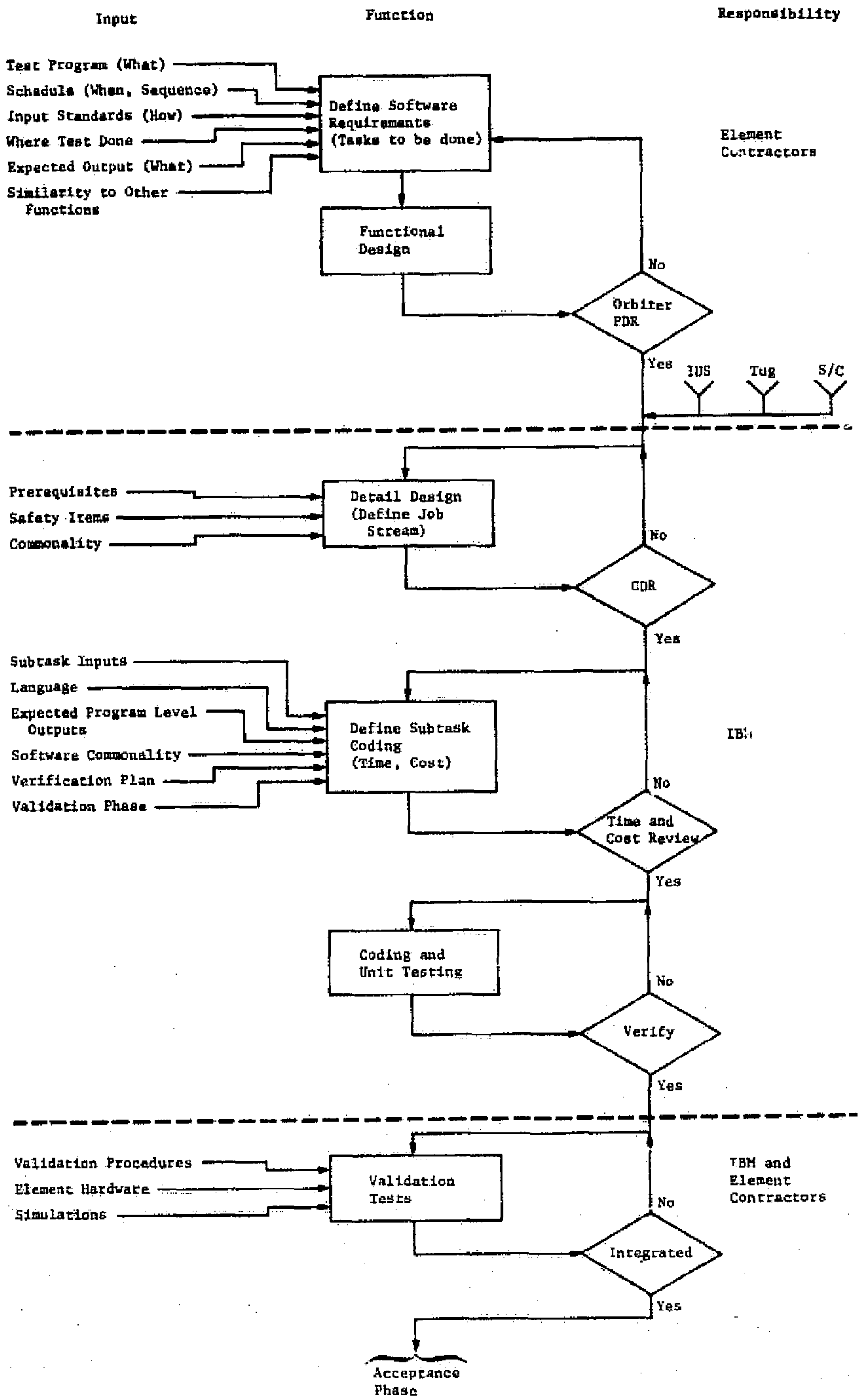

Figure II-23 LPS Software Development Process

During the transition phase from IUS to Tug, it appears that every possible combination of old and new software will exist. The software system will have to respond to every kind of demand or request possible. The user will have the best insight into his own requirements and probably will do his own software requests. The LPS software contractor's role will be to standardize many different requests and consciously maintain software commonality throughout the program. The transition phase transfer from IUS to Tug will not be a big step function because of previous development and partial dual usage of modular form software, which will easily be fitted into the Tug LPS programs.

6.0 Software Restraints

During the acquisition phase there are a number of operational software-related restraints that must be considered early to prevent or reduce operational problems later on. These restraints may be classified as: (1) software constraints on hardware; and (2) hardware impacts on software. There are, of course, other restrictions, such as economic, human error, quality of validation hardware, etc. These restrictions can be minimized through an orderly, controlled approach to software development.

6.1 Software Constraints on Hardware

Normally software can conform to the hardware design. However, there is a possibility that software may dictate the number of interface lines between the spacecraft and the Orbiter (through the Tug). The number of lines can also impact the interfaces on both ends of the Tug.

6.2 Hardware Impacts on Software

Examples of hardware impacts are: number of operations required per second, operations timing requirements, operations sequence and interlocks, and access to hardware for software installation.

J. LOGISTICS/MAINTENANCE

1.0 Maintenance and Refurbishment Operations

Spacecraft maintenance will be performed at the Spacecraft Processing Facility. The IUS can be processed with Tug in a common facility at the VAB or in a separate area if SAEF-1 becomes the Tug Processing Facility (TPF). Level I Tug maintenance will be performed at the TPF and consist primarily of LRU removal and replacement based on fault detection and isolation. After post-landing operations, separation from the spacecraft at the OPF, and receipt at the TPF, the Tug will undergo a complete visual inspection for structural degradation, subsystem integrity, and general cleanliness. In-flight data will be correlated with the

results of ground checkout and inspection to establish the ground operations maintenance plan. The objective is to reduce Tug fixed-schedule maintenance through condition-assessment techniques that target existing or probable failures. In support of Level I activities, Level II servicing, calibration, alignment, rebuild, and verification will be performed at KSC repair shops. Level III repair, overhaul, and verification will be accomplished at Tug contractor's or supplier's facility during the manufacturing cycle and at NASA/Air Force depots thereafter. The majority of WTR-related maintenance activity will be performed at the KSC TPF.

Fleet Management will plan, schedule, and control overall Tug maintenance. The contractor's maintenance engineering analysis, as an element of support requirements analysis, will establish maintenance tasks, task times, facility interface, personnel skill levels, and necessary tools and equipment. Maintenance level and location, repairable/nonrepairable status, repair locations, and necessary spares, bulk items, and consumables will be established. Table II-9 summarizes the more important maintenance concept considerations elicited by this study. Standardization of connectors, servicing points, and support equipment, as well as considerations for maintenance access, replacement/repair within timeline constraints, and general implementation of the LRU concept must be coordinated during spacecraft, IUS, and Tug support requirements analyses and reflected in design to facilitate postmate maintenance operations at the TPF. Program operational maintenance/refurbishment plans should be developed to control overall activity. Control functions for fleet and individual maintenance will include status reporting, plan revision, spares provisioning and reorder, reassessment/assignment of maintenance task times, propellant/pressurant forecasts, and modification kit installation scheduling. Of paramount importance will be fleet management involvement in development of postflight maintenance activity plans.

The engineering model flow will verify maintenance and overall logistics planning and state of preparation for the operational program. Operations at the TPF will be monitored and scored to evaluate maintenance procedures and the maintenance task timeline. OFI data will be prepared in conjunction with a postflight maintenance activity plan to simulate component failure and exercise the repair/replace cycle. Availability, accuracy, and adequacy of maintenance location, level, documentation, tools, skills, and equipment will be assessed. Problems will be factored into support analysis and planning, procedural changes will be made, and support equipment deficiencies will be corrected to provide a "ready" logistics and maintenance program for the first flight article.

Table II-9 Maintenance Concept Considerations

Level I	Level II	Level III
Scheduled and unscheduled inspection, servicing, malfunction isolation, removal, replacement, verification, and subsystem checkout. Normally performed at TPF. Includes vehicle and support equipment. Provides for replacement at highest practical assembly level (LRU) based on: Scheduled intervals for time or cycle sensitive items; Condition monitored item replacement due to indicated degradation/failure. Malfunction assessed by on-board performance monitor system, maintenance recorders, and onboard display augmented by ground display and control. Predicated on postflight maintenance activity plan and work package. Minimum scheduled maintenance planned.	Off-line maintenance activities in support of Level I maintenance. Supports failure verification and minor LRU repair. Includes servicing, calibration, alignment, rebuild, and verification. Normally performed at KSC repair shops unless capability exists only at Tug manufacturer or supplier. Relies heavily on installation of Shop Replaceable Units (SRUs). Optimum Repair Level Analysis (ORLA) may be used to help define repair activity.	Off-line maintenance activities in support of Level I and II maintenance. Includes repair, overhaul, and reverification of LRUs and SRUs. Provides capability for detailed failure analysis. Performed at Tug contractor or supplier during manufacturing cycle and at NASA/Air Force depots thereafter. Provides for traveling technical team assistance from manufacturer/supplier to KSC.

Maintenance and repair activities will vary considerably between Tug and IUS based on major differences in size and configuration and on the reusability aspects of Tug versus IUS. Maintenance planning for postflight refurbishment is a necessity for Tug and nonexistent for an expendable IUS. GSE/TSE maintenance and spares are different except for possible common-use items such as the APS servicing/deservicing unit, the helium pressurization system, the ground payload manipulators, and the PCR access platforms.

Postmate spacecraft maintenance and repair will be minimal, but contingency actions will be established by Spacecraft supervisory representation to the IUS/Tug processing team and spacecraft technicians will accomplish repair/replacement with support from IUS/Tug personnel.

2.0 Spares Support

Delayed procurement of spares for some Tug LRUs will be necessary based on probability of design change, anticipated high cost items, and desired experience factor in new technology areas. Spares will be drawn to the greatest extent possible from production inventories. Selected production components will be maintained at the TPF or in adjacent spares warehousing for Level I maintenance. Components not considered critical to the maintenance flow will be retained at the contractor's facility or at a depot and shipped on an as-required basis. Production items used as spares will be replenished by provisioning action. When the production cycle nears completion, and spares requirements are better defined based on usage, major spares provisioning action will be established.

A typical Tug spares flow is presented in Figure II-24. Fleet management will select spares based on review of the contractor's required spare parts lists. The selection process will determine quantity, need date, and allocation requirements. Production spares, drawn from the manufacturer's production items, and provisioned spares will be shipped to KSC to establish the spares inventory. A mechanized inventory control program will have to be developed to provide, as a minimum, a spares list, spares due in status, site use and allocation, and spares inventory status.

Configuration control of spares will be maintained through the engineering control system. During the engineering model flow in support of activation activities, requirements for spares will be generated to judge on-site availability and processing and to assess the delivery loop on production spares shipped from the manufacturer.

While deferred spares acquisition is a necessity for Tug, the expendable IUS will require only critical item spares to cover preflight maintenance operations. Common warehousing of IUS/Tug spares would have as its only feature multiple use of a facility and could create problems due to differences in DOD and NASA inventory systems. Errors in statusing and issuance could be increased under a common system. Spacecraft spares in support of postmate maintenance would normally be drawn from the SPF. Unique requirements for spacecraft spares not under control of the spacecraft agency would have to be procedurally documented or indicated by a special considerations decal or attachment to the spares. This would be a responsibility of the spacecraft agency.

Figure II-24

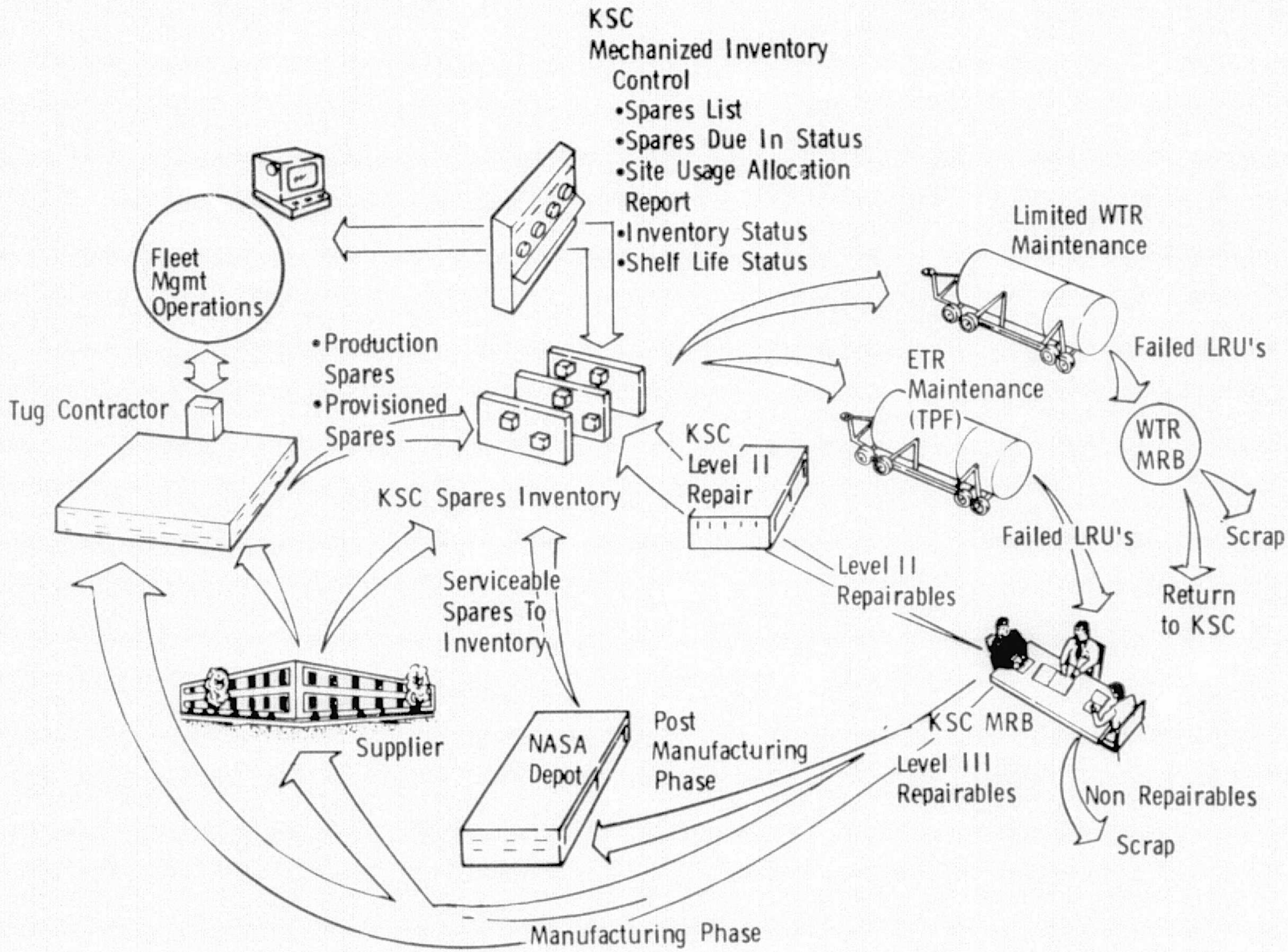

Figure II-24 Typical Tug-Spares Flow

3.0 Training and Certification

Maximum use should be made of contractors' training programs to satisfy NASA and DOD requirements on IUS, Tug, kick stage, and spacecraft. These programs will normally encompass system familiarization, detailed subsystem and component operation, transportation and handling procedure, and skills training suitable to the manufacturing and test processes. When training requirements analyses are developed for contractor training, NASA and DOD requirements should be considered so that maximum commonality in training application can be achieved, as represented in Figure II-25. Video tape techniques should be considered for training areas not subject to a high change level. Special emphasis should be placed on contractor-developed training, which stresses the interpretation of operational flight instrumentation as a maintenance prediction technique. This is especially true for Tug where the refurbishment cycle places greater importance on failure or probable failure prediction. The Tug engineering model, or available test articles, should be used to provide high fidelity training on actual hardware for ground crews in both the maintenance and handling areas.

Normal attrition, design change, and the requirement for recertification in skill areas will require on-going training during the operational phase. Contractors can supply this training, to supplement KSC training, through live and video presentations on site at KSC or other NASA/DOD centers. Training scope and level of detail should be aligned with Level I and II maintenance and checkout requirements as established by the contractors' support requirements analyses. Contractor sustaining engineers can further implement the training process by providing support for job experience training on site at KSC or WTR.

Training, with the exception of common GSE, is IUS- and Tug-peculiar and unique to the separate crews that will process them. Unless spacecraft present a potentially hazardous condition during postmate operations or require special handling provisions, training of IUS/Tug personnel by the spacecraft agency is not anticipated for maintenance operations. Spacecraft agency personnel who operate in support of IUS/Tug processing teams will require KSC training/certification on safety, facility interface, and clean room operation.

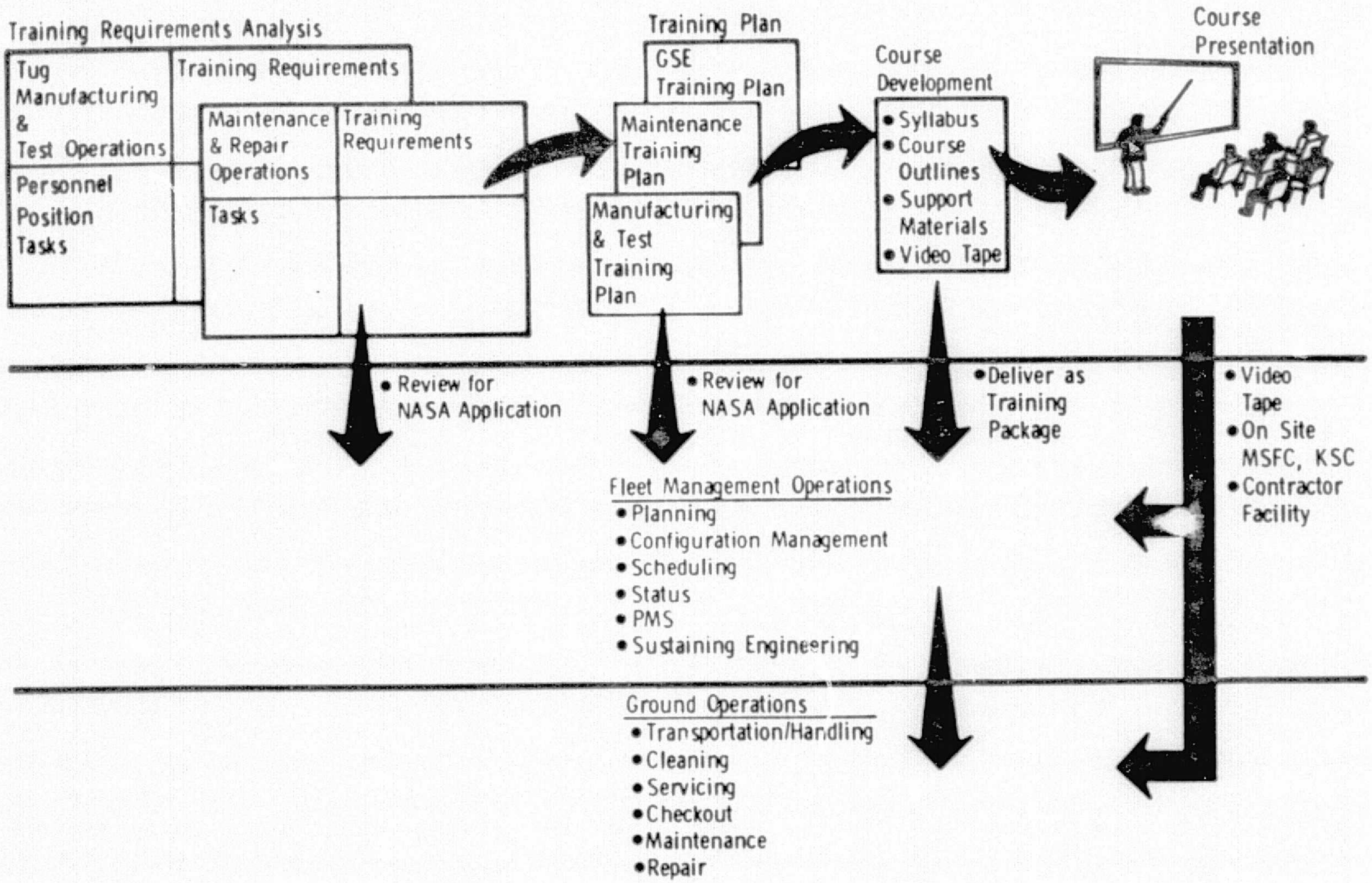

Figure II-25 Training Development Approach

4.0 Operations and Maintenance Documentation

Contractors' support requirements analyses will yield the type, content, depth, and format of operations and maintenance documentation appropriate for their modules. These requirements will be correlated with the documentation structure, depth, and format required by KSC for development of operations and maintenance instructions, O&M plans and subtier data. It is suggested that the contractors develop operations and maintenance manuals (O&M manuals) as the data base for program documentation as indicated in the Tug data development shown in Figure II-26. O&Ms, as well as supportive engineering documentation, could be stored in the contractors' mechanized data bank for rapid retrieval in support of NASA/DOD use or update. Hard copy could be obtained at the contractors' facilities and reproduced and shipped to using agencies or a remote terminal system could be established for call up and display. O&M manuals could also be stored by processing data on microfiche for storage with subsequent transmittal via on-site viewers and printers.

Like training, O&M documentation requirements are unique to IUS and Tug based on configuration differences and location differences, even on common equipment. Spacecraft also will develop their own peculiar data requirements and will input to the post-mate procedures as required.

5.0 Facility and Equipment Requirements

Tug logistics facility requirements for operational support will include adequate floor space, commodity interface, and installed equipment at the TPF to accomplish Level I maintenance, a minimal, but dedicated, training area with video equipment at the TPF or in adjacent NASA facilities, an adequate spares storage and processing area, and a storage and issuance area for documentation.

Maintenance equipment, including electronic and mechanical test equipment, lubrication and servicing equipment, and common and special tooling, will be housed and maintained to the greatest extent possible at the TPF. Repair and servicing beyond TPF capability will be performed at KSC repair shops, supplier's facilities, or at depot level.

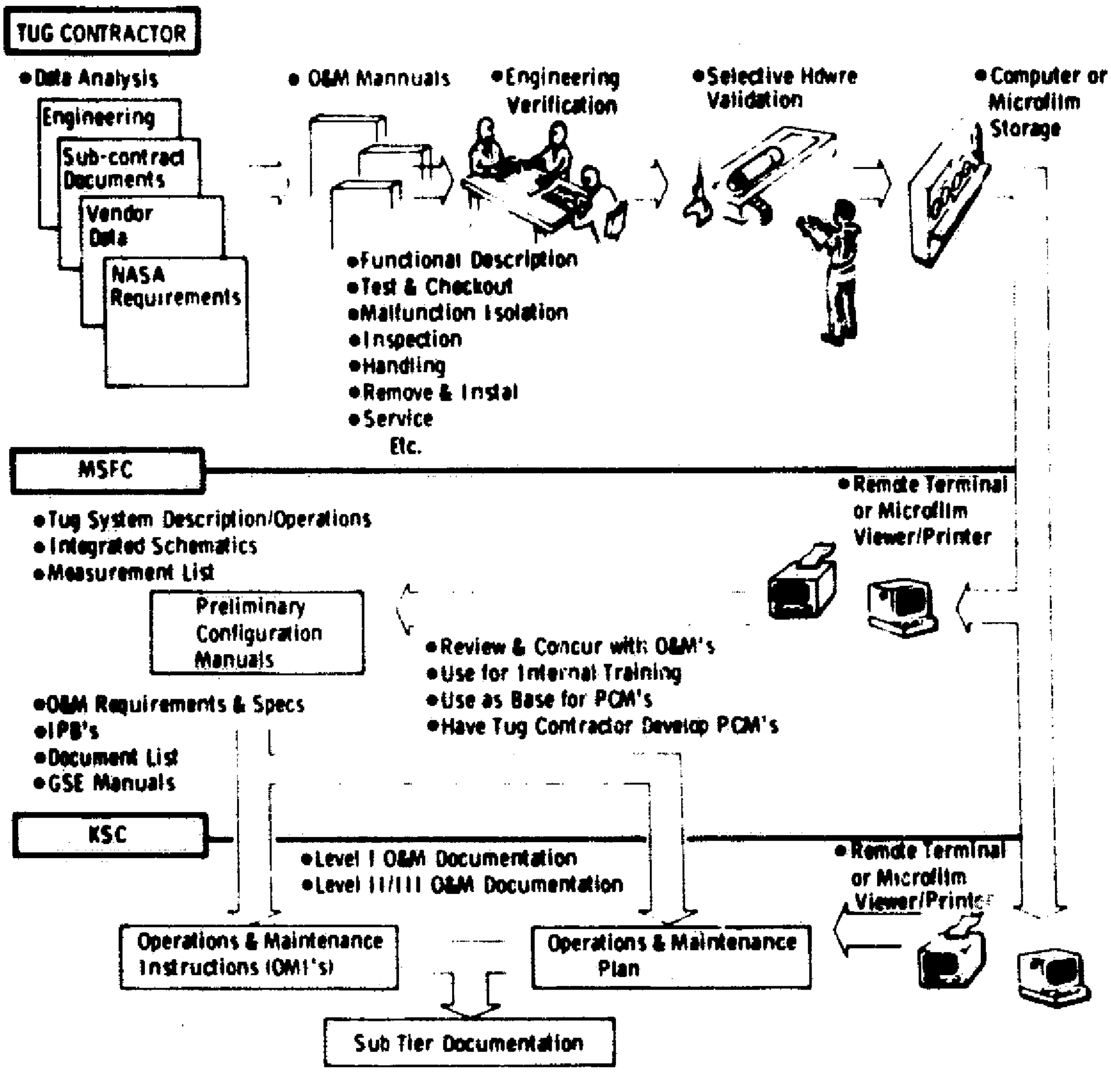

Figure II-26 Tug Operation and Maintenance Documentation Development

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K. CONFIGURATION MANAGEMENT

1.0 Program Objectives

Configuration management should provide the necessary procedures and disciplines to achieve effective control over the hardware, software, and operational activities during site activation, operations, and transition from IUS to Tug. This control will be needed on a continuing basis throughout the life of the project. The objective of configuration management is to insure the maximum operational capability through formal initial identification of configuration, controlled approval of changes, and continuing and accurate recording of the exact configuration of systems and selected equipment. Recommendations for the implementation of configuration management during the various phases of the project are discussed below.

2.0 Requirements and Responsibilities

Fleet configuration management requires that the project configuration management plan be prepared, coordinated, imposed, and maintained for the Tug project. This plan should identify the configuration management responsibilities at all levels. It would include the coordination of interface activities and the inputs to the basline end item specification. The plan should also describe how the baseline documentation would be managed through a systematic change control process at various levels that would provide Tug configuration status and verification data. It would be the responsibility of configuration management to audit contractors and subcontractors to assure that their configuration management systems are enforced and are compatible with the minimum requirements established by NASA.

3.0 Configuration Identification

Figure II-27 illustrates the interrelationship of NASA and DOD project documentation. For the sake of economy and commonality of requirements, design and equipment, it is recommended that early in the program MSFC establish an interface between the several NASA centers, DOD agencies, element contractors, and payload contractors to exchange appropriate information for incorporation into the Tug ground operations system.

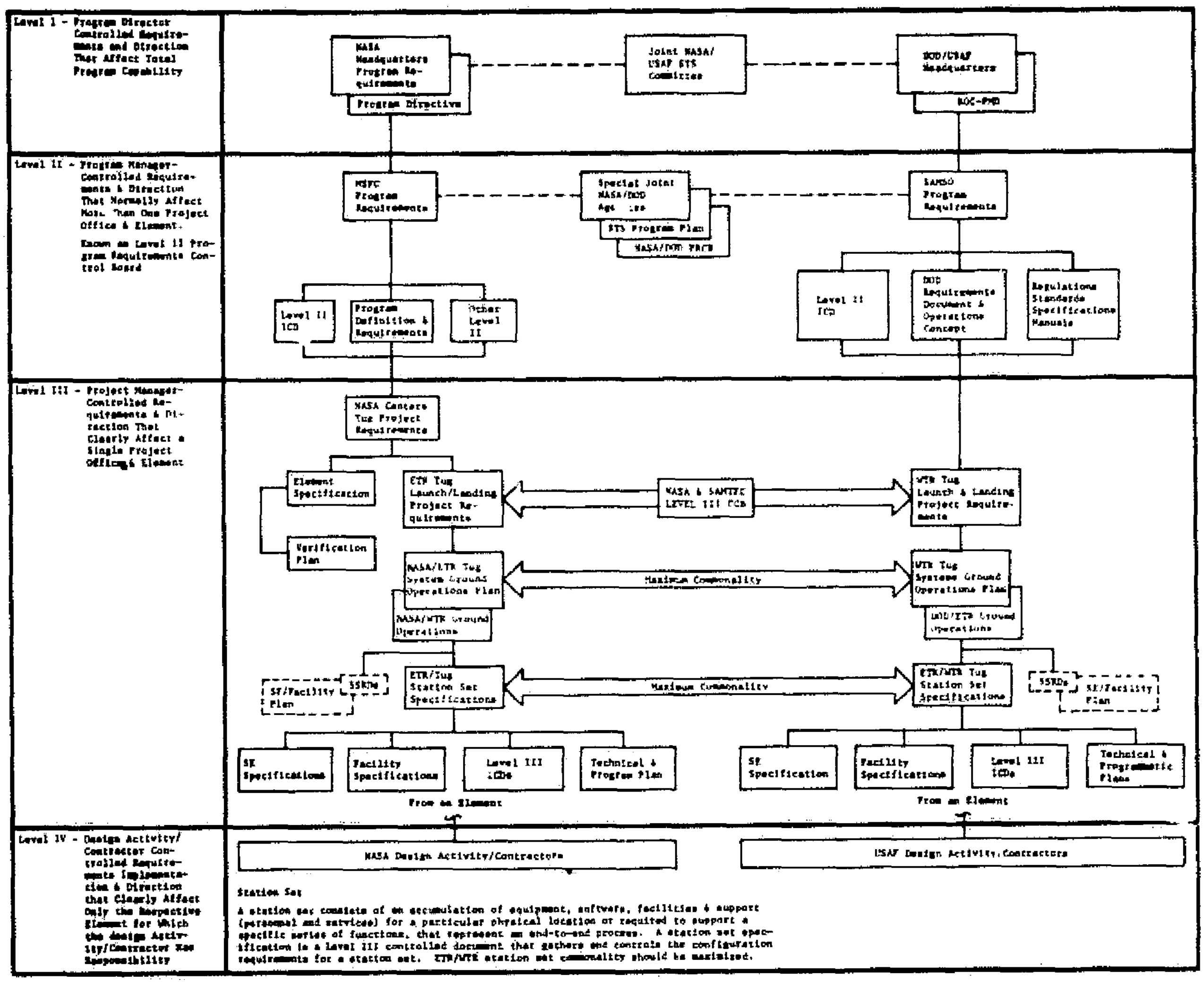

Figure II-27 Interrelationships of NASA and DOD Requirements Documents

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4.0 Operational Considerations

During the operational phase of the project, maintenance of the Facility Criteria and Interface Document should be suspended and the baselined A&E drawings should become the authorized configuration and, therefore, the specification for the facility. The proposed system of maintaining only the A&E drawings after baselining of the facility will be successful only if the drawings are maintained diligently. These drawings are updated to the latest configuration through the FCR/FECP loop. Maintenance of the facility document would be meaningful only if facility construction was on a production-type basis.

The same agencies and contractors involved in the interface change coordination and approval loop are also members of the Facility working Group (FWG). All facility changes are originated as FCRs and coordinated through the FWG. Therefore, the FCR is an adequate medium for coordinating facility interface problems.

L. TIMELINE FUNDING

Tug timeline funding for the Tug program ground operations was treated in two phases: DDT&E and operations. The costs presented reflect the recommended option 6 cost of processing the Tug in a factory-clean environment in the VAB. The funding diagrams represent an estimated program cost each year based on 1974 dollar labor rates currently used by the Martin Marietta Corporation and a constant direct labor overhead rate of 110%, which was a NASA-directed rate applied to this study. Due to different accounting practices, management and administrative rates, overhead and computer unit costs are estimated as if the work were performed at Martin Marietta's Denver Data Center for all computer costs shown in the software WBS item. All major material procurement such as spares, propellants, and gases were treated as GFE with no rates applied.

Table II-10 displays the estimated activation cost differences between the various processing options considered in this study. The cost of option 6 was spread through the DDT&E phase, from 1980 thru 1983, along with the projected manpower buildup as shown by Table II-11.

Table II-10 Activation Cost Consideration, $ in Millions

	Options						
	Clean Processing			Factory-Clean Processing			
	1	2	3	4	5	6	7
Tug Unique GSE	13.53	8.62	8.62	8.35	8.10	7.49	7.49
Tug Facility Modification	6.10	5.96	5.92	10.69	6.18	5.90	6.09
IUS Unique GSE	0.20	0.20	0.20	0.20	0.20	--	--
IUS Facility Modification	0.30	0.27	0.27	0.33	0.45	0.06	0.06
Kick Stage GSE	3.06	2.80	2.80	2.79	2.80	2.80	2.80
Launch Pad/PCR, OPF and Warehouse	0.57	0.57	0.64	0.57	0.57	0.57	0.57
Total	23.76	18.42	18.45	22.93	18.30	16.82	17.01
Rating	3	1	2	4	3	1	2

The resulting cost of the DDT&E phase is shown below in Table II-11.

Table II-11 Ground DDT&E Timeline Funding, $ in Millions

Function	1980	1981	1982	1983	Total
Fleet Utilization Project Management	0.26	0.50	2.07	4.78	7.61
Ground and Launch Operations, ETR	0.62	1.19	2.47	19.67	23.95
Ground and Launch Operations, WTR	--	0.50	2.52	1.96	4.98
DDT&E Phase Total	0.88	2.19	7.06	26.41	36.54

Operations phase funding from January 1984 thru December 1991 is shown in Table II-12.

Fleet utilization project management costs represent the cost of project level cost/performance management depot maintenance, long-range scheduling of the Tug fleet, and sustaining engineering.

Ground and launch operations at WTR indicate the cost of the launch/recovery support crews, propellants, spares, and facility maintenance.

Ground and launch operations at ETR indicate the cost of the operational crews supporting refurbishment at the central processing facilities and checkout crews, facility maintenance costs, propellants, spares and central warehousing.

Table II-12 Operations Phase Timeline Funding ($ in Millions)

Project Function	Calendar Year 1984	1985	1986	1987	1988	1989	1990	1991	Total
Fleet Utilization Project Management	7.22	7.46	7.64	6.97	6.97	6.75	7.86	7.39	58.26
Ground and Launch Operations, ETR	5.78	6.21	6.21	5.87	5.87	5.70	6.38	6.21	48.24
Ground and Launch Operations, WTR	0.84	0.60	0.84	0.60	0.60	0.60	0.84	0.60	5.52
Ground Operations Total	13.85	14.27	14.70	13.44	13.44	13.06	15.08	14.21	112.05

The total ground operations task yearly funding is shown in Figure II-28. The cost fluctuations could be smoothed during the DDT&E phase by rescheduling the construction costs. The minor perturbations in the operational phase are due to variations in annual launch rates.

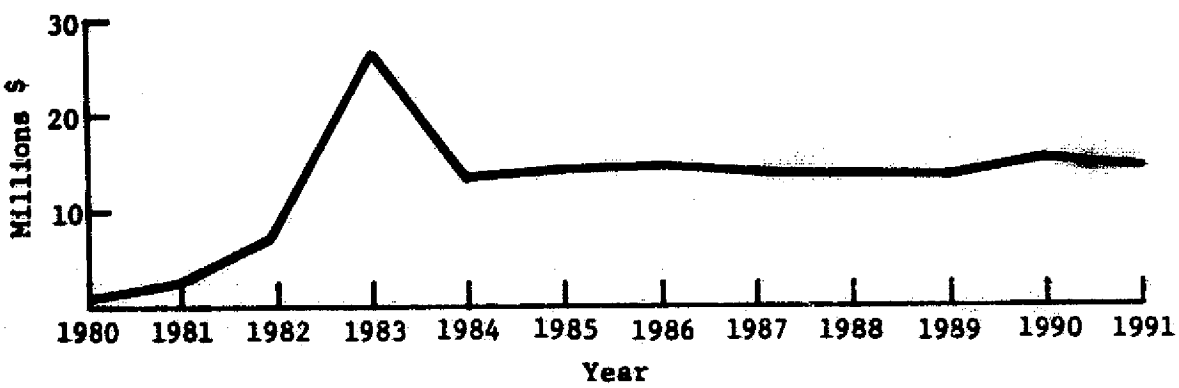


Figure II-28 Tug Ground Operations Yearly Funding

These data summarize the detailed estimate of all the personnel, material, facilities, GSE, maintenance and travel costs based on study results and data accumulated from similar programs within Martin Marietta's aerospace experience. Evaluation of site modification costs and maintenance at ETR and WTR was performed by personnel familiar with the requirements of these particular sites. Evaluation of the personnel requirements at each of the three project functions were made by engineering personnel familiar with the types of task requirements peculiar to the site function. Materials were priced using current known costs, spares costs were forecast from results of an earlier study. All items were compiled using a computerized cost proposal model with appropriate overhead rates and factors applied. Refer to the cost volume (Volume III) for detailed information.

CONTENTS

III. SUBPLANS

A. TUG OPERATIONAL SUBPLAN

1.0 Introduction

This subplan defines the single cycle turnaround plans and resource requirements for an operational Tug. The plan is based on processing in a 100K clean area. Addendum 6 details the recommended factory clean processing.

Fleet size (active and total) and total resource requirements to accommodate that fleet size are defined in the Fleet Utilization Subplan B. Processing requirements and timelines for the first flight Tug are discussed in the Site Activation Subplan D, and IUS to Tug transition is discussed in Subplan E. All requirements and planning shown within this subplan are based on an operational period after the learning curve has flattened, and after initial activation and early flight problems have been experienced and resolved.

Turnaround flow and resource requirements are summarized in this plan. Detailed requirements and specifications for resources are included in Appendixes A through E.

The ground operations approach used to develop the Tug operational subplan is illustrated in Figure III-A-1.

The basic approach has been to analyze the MSFC baseline Tug and supporting documentation to define operations required for refurbishment and checkout at the launch sites. Where existing documentation was inadequate, ground rules were established on which to proceed. Areas that affect the ground checkout, maintenance, refurbishment, and launch were analyzed to identify operational impacts, and costs that would affect the Tug, and consequently the Shuttle program. Where basic philosophies were required before detailed requirements could be defined, we developed and coordinated these philosophies.

At the outset, the ground rules used were those set forth in the *Baseline Space Tug Ground Operations: Verification, Analysis and Processing Document*, 68M00039-4. As this study and the four concurrent studies evolved, basic ground rules, assumptions, and approaches were generated to better fit the operations required. These are documented in para 2.0.

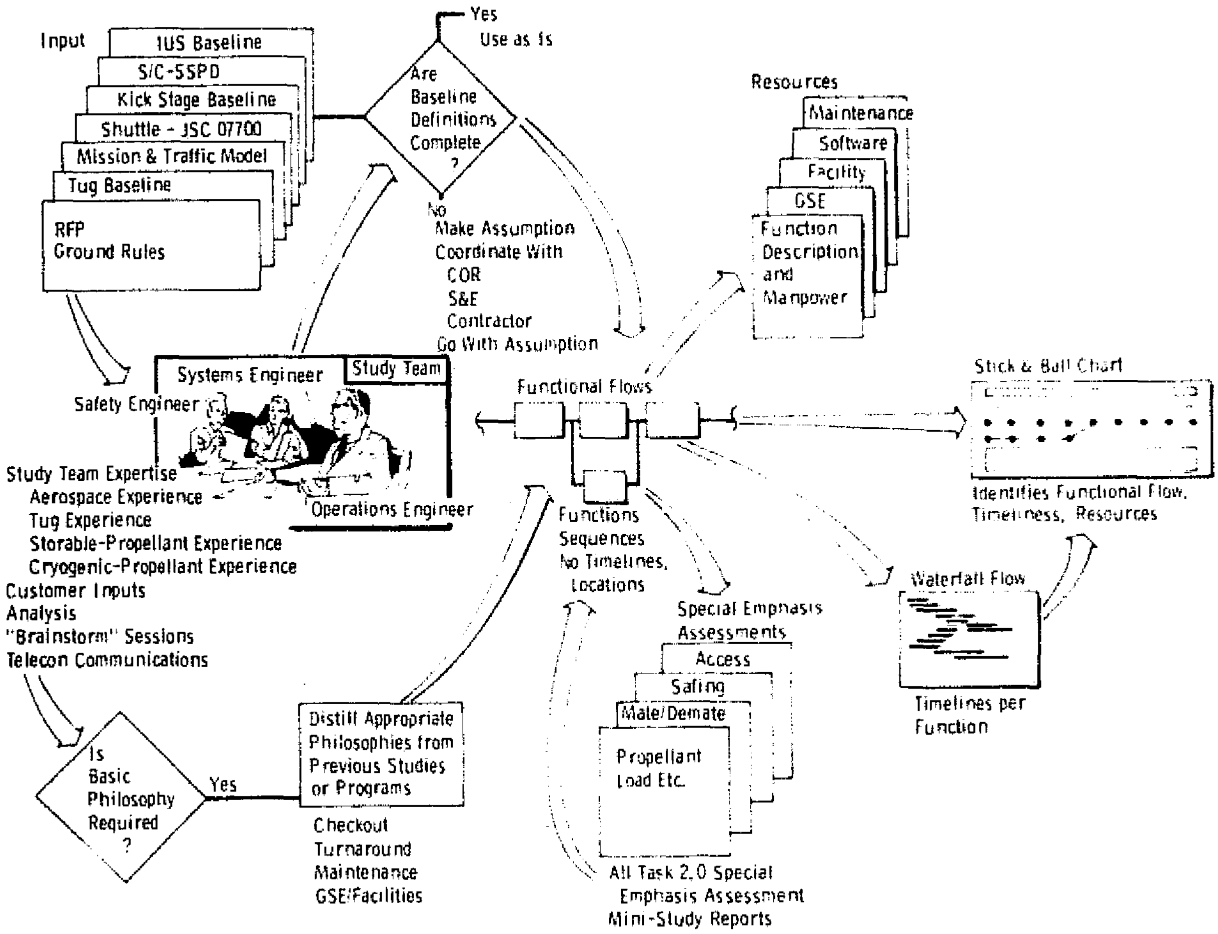


Figure III-A-1 Ground Operations Methodology

Tug ground turnaround time was determined through a systematic analysis of each function required to refurbish and checkout a returned Tug, mate it to a spacecraft and to the Shuttle and launch. It was determined that a single Tug could be turned around within the allocated Orbiter turnaround time with a crew of 80 people working two shifts per day, five days a week.

Facility utilization at ETR and WTR was addressed in detail starting from certain broad facility/location philosophies. In establishing these philosophies, we drew heavily on previous study results where applicable.

We baselined a Common Tug Maintenance and Checkout Facility (CTMCF) over dedicated ETR and WTR facilities. A study performed last year shows significant savings in a CTMCF approach if the WTR Tug traffic is low (Ref VI-5). The traffic model, which was the baseline early in the study, shows WTR Tug flight ranging from 5 to 8

per year. However, subsequent inputs to be used in this study indicate that a substantially reduced number is more realistic. Addendum 7 documents a special emphasis assessment performed as part of this study. It describes the capability of the WTR facility in more detail and provides our recommended WTR deltas to accommodate Tug launches.

A common NASA/DOD facility was selected for Tug processing over dedicated facilities. The baseline traffic model reflects a combined NASA/DOD Tug flight density ranging from 24 to 37 per year. Until the full impact of classified payloads is defined, it is assumed that security can be handled in a common facility, if properly planned.

The study baselines Tug to spacecraft mate and integration off-pad at ETR. The heavy traffic through the PCR (all payload-Tug and non-Tug) at ETR precluded routine mating at the pad. However, the option of vertical integration at the PCR is provided for priority payload changeout. At WTR, the traffic is much lighter, and the PCR design is more suitable for checkout. Consequently, the study assumes a WTR delta of Tug to spacecraft mate and integration with the Orbiter on the launch pad.

The study baselines payload to Shuttle mate at the pad rather than at the OPF based on previous study recommendations, the results of our analysis that show approximately a 60-hour reduction in Tug processing time over OPF installation, and the improved capability of the ETR PCR concept.

The detailed GSE requirements and quantity required for ETR and WTR are documented on the GSE requirement specification sheets in Appendix B. The approach in the conceptual design of the GSE is to make it as versatile as possible and, in most cases, portable to the extent that it can be used in various locations during refurbishment and checkout activities.

The LPS concept for centralized automatic checkout and monitoring of the complete Shuttle system, including Tug, at both launch sites, was used for this study. This study assumes that a computer remote station with input/output (I/O) equipment will be available for dedicated Tug usage off line as well as after installation in the Orbiter.

Detailed facility requirement sheets, maintenance, and software requirement sheets are contained in the appendixes and summarized in the subplan.

2.0 General Requirements

Throughout the Tug operational phase study, certain ground rules and guidelines were established in order to accomplish the operations analyses and establish GSE and facility requirements.

2.1 Ground Rules

1) Tug ground operations times are based on a five-day work week, with two shifts per day at ETR and one shift per day at WTR.

2) Do not impact Orbiter times allocated in KSC flow, dated June 21, 1974. (20 hours OLF/OPF or 24 hours on-pad.)

3) The spacecraft is flight-ready when it is received for Tug/spacecraft integration.

4) No maintenance of the Tug will be performed while the Tug is in the Orbiter bay.

5) Tug main propellant will be dumped and tanks purged on-orbit.

6) Abort flight sequence will dump Tug oxidizer only before Orbiter landing.

2.2 Guidelines

1) Checkout is based on the "last flight is the best test" philosophy.

2) LPS is primary mode of ground checkout.

3) Avionics alignment will be accomplished off Tug.

4) A hybrid maintenance will be used.

5) Tug to be processed 100K clean.

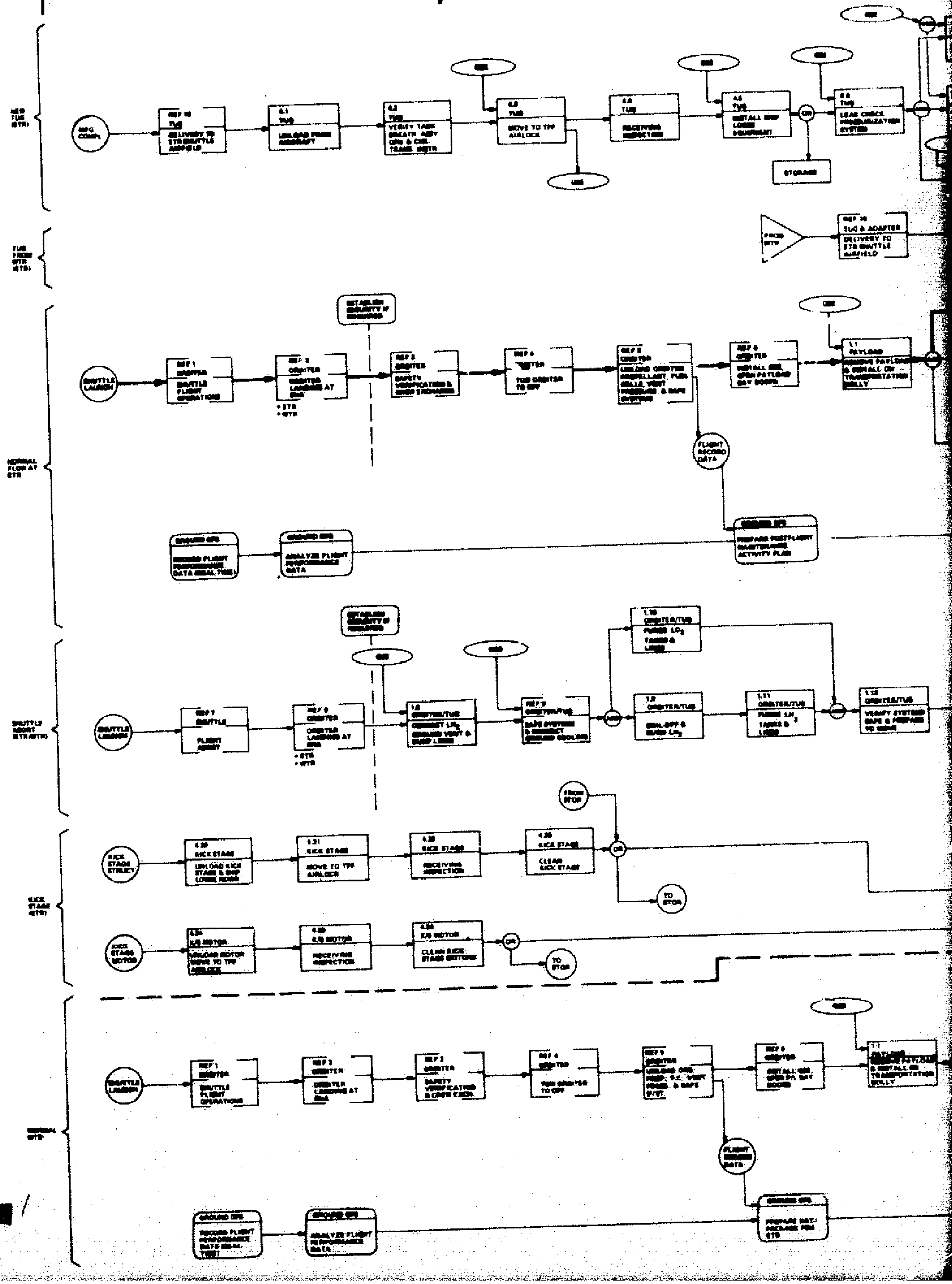
3.0 Operational Phase Study Elements

3.1 Ground Operations Flow

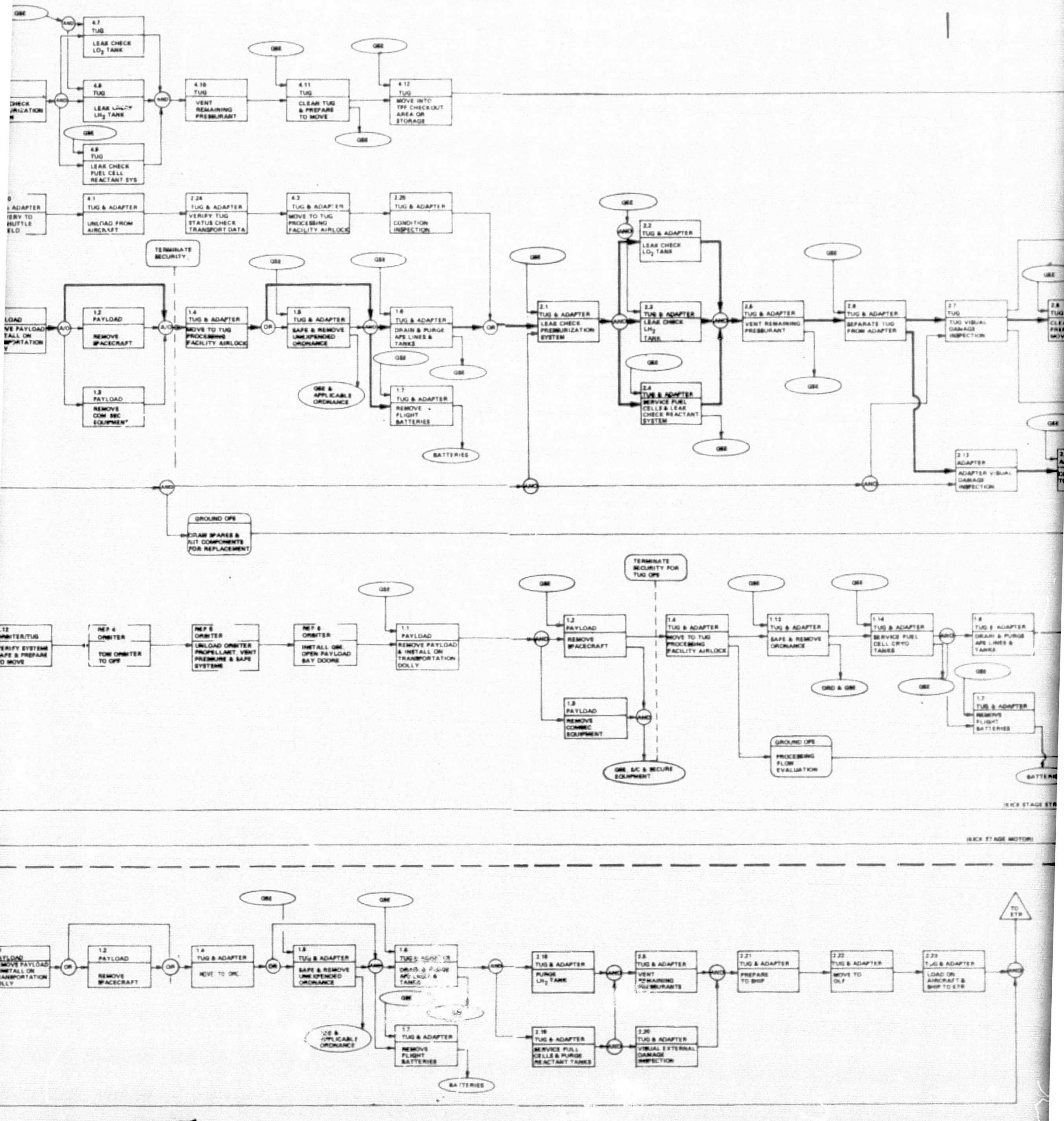
The Tug ground operations processing in a 100K clean area is shown in Figure III-A-2. Factory clean processing, which is our recommended approach, is shown in Addendum 6. The highlighted flow (heavy line) is the "green light" flow used for determining operational crew sizes and timelines. Under normal conditions, contingency situations are assessed in subplan B and addendum 4. The flows shown in parallel are optional approaches or contingency flows. Functions that have no active Tug participation are shown as a dashed functional block while those with active Tug participation is a solid functional block. The functional block number is a

7

ST TEST
E EXTENT
ES ARE EXPENDED OR VENTED BEFORE
OF GUIDANCE COMPONENTS IS ACCOM-
A PLATE OR TRUSS THAT IS MECHANICALLY
STRUCTURES



FOLDOUT FRAME



FOLDOUT FRAME 2

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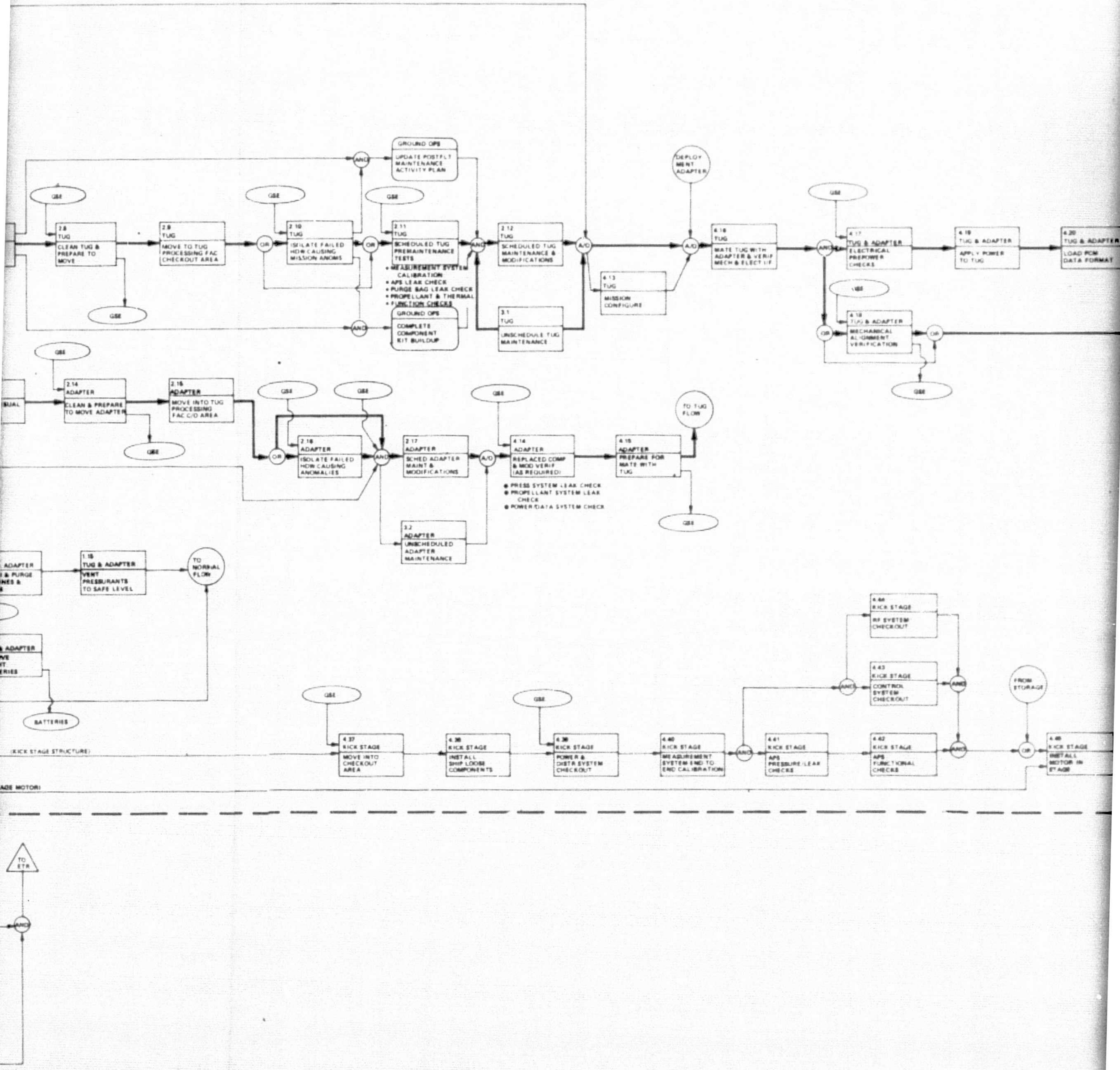
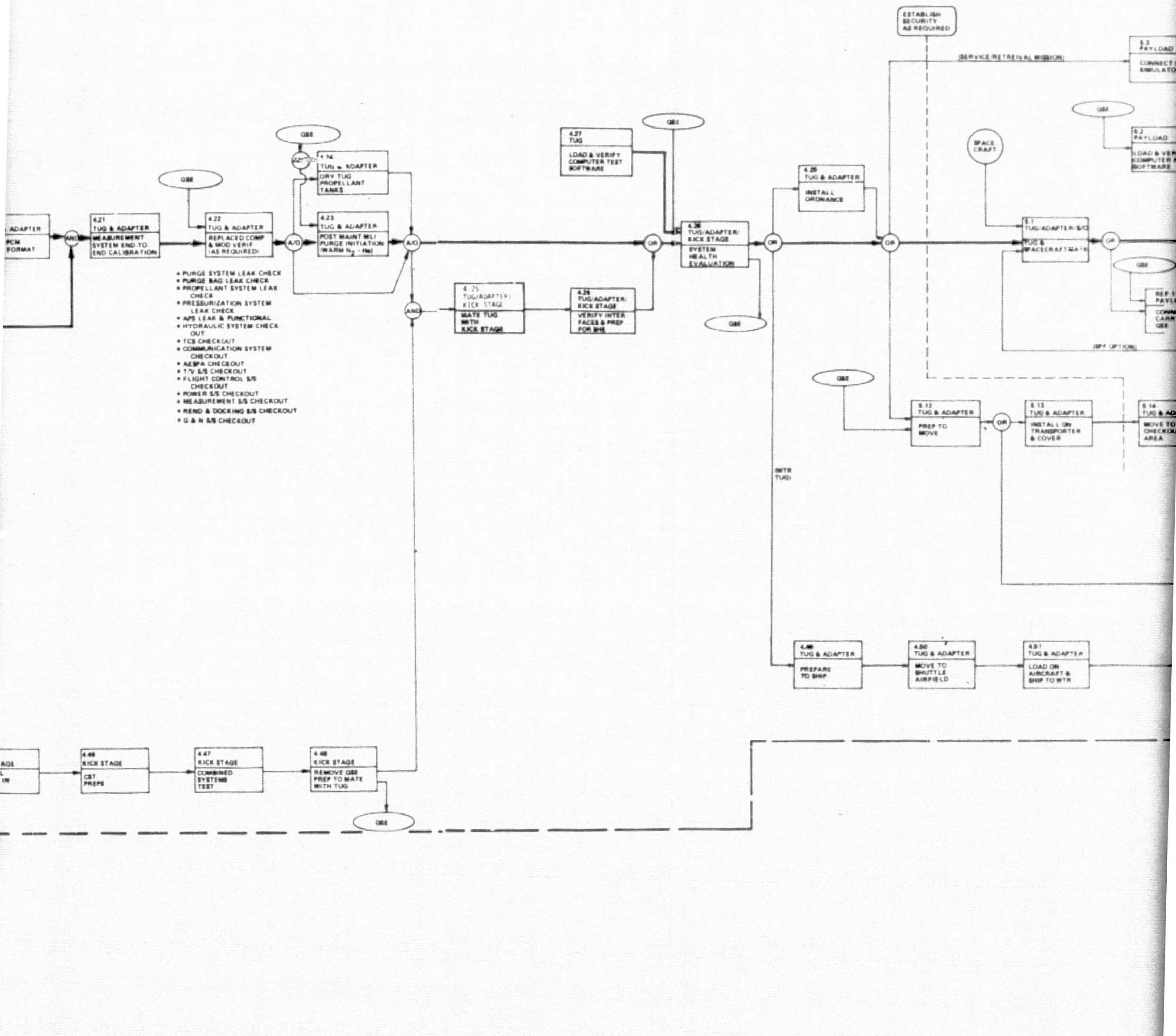

GROUND OPS
UPDATE POSTFLT MAINTENANCE ACTIVITY PLAN
GSE
2.8 TUG
CLEAN TUG & PREPARE TO MOVE
2.9 TUG
MOVE TO TUG PROCESSING FAC CHECKOUT AREA
OR
2.10 TUG
ISOLATE FAILED HDW CAUSING MISSION ANOMS
2.11 TUG
SCHEDULED TUG PREMAINTENANCE TESTS
• MEASUREMENT SYSTEM CALIBRATION
• APS LEAK CHECK
• PURGE BAG LEAK CHECK
• PROPELLANT & THERMAL
• FUNCTION CHECKS
GROUND OPS
COMPLETE COMPONENT KIT BUILDUP
AND
2.12 TUG
SCHEDULED TUG MAINTENANCE & MODIFICATIONS
3.1 TUG
UNSCHEDULE TUG MAINTENANCE
A/O
4.13 TUG
MISSION CONFIGURE
DEPLOYMENT ADAPTER
4.16 TUG
MATE TUG WITH ADAPTER & VERIF MECH & ELECT I/F
4.17 TUG & ADAPTER
ELECTRICAL PREPOWER CHECKS
4.18 TUG & ADAPTER
MECHANICAL ALIGNMENT VERIFICATION
4.19 TUG & ADAPTER
APPLY POWER TO TUG
4.20 TUG & ADAPTER
LOAD PCM DATA FORMAT
2.14 ADAPTER
CLEAN & PREPARE TO MOVE ADAPTER
2.15 ADAPTER
MOVE INTO TUG PROCESSING FAC C/O AREA
2.16 ADAPTER
ISOLATE FAILED HDW CAUSING ANOMALIES
2.17 ADAPTER
SCHED ADAPTER MAINT & MODIFICATIONS
3.2 ADAPTER
UNSCHEDULED ADAPTER MAINTENANCE
4.14 ADAPTER
REPLACED COMP & MOD VERIF (AS REQUIRED)
• PRESS SYSTEM LEAK CHECK
• PROPELLANT SYSTEM LEAK CHECK
• POWER/DATA SYSTEM CHECK
4.15 ADAPTER
PREPARE FOR MATE WITH TUG
TO TUG FLOW
1.15 TUG & ADAPTER
VENT PRESSURANTS TO SAFE LEVEL
TO NORMAL FLOW
BATTERIES
(KICK STAGE STRUCTURE)
4.37 KICK STAGE
MOVE INTO CHECKOUT AREA
4.38 KICK STAGE
INSTALL SHIP LOOSE COMPONENTS
4.39 KICK STAGE
POWER & DISTR SYSTEM CHECKOUT
4.40 KICK STAGE
MEASUREMENT SYSTEM END TO END CALIBRATION
4.41 KICK STAGE
APS PRESSURE/LEAK CHECKS
4.42 KICK STAGE
APS FUNCTIONAL CHECKS
4.43 KICK STAGE
CONTROL SYSTEM CHECKOUT
4.44 KICK STAGE
RF SYSTEM CHECKOUT
FROM STORAGE
KICK STAGE
INSTALL MOTOR IN STAGE
TO ETR

4



FOLDOUT FRAME 4

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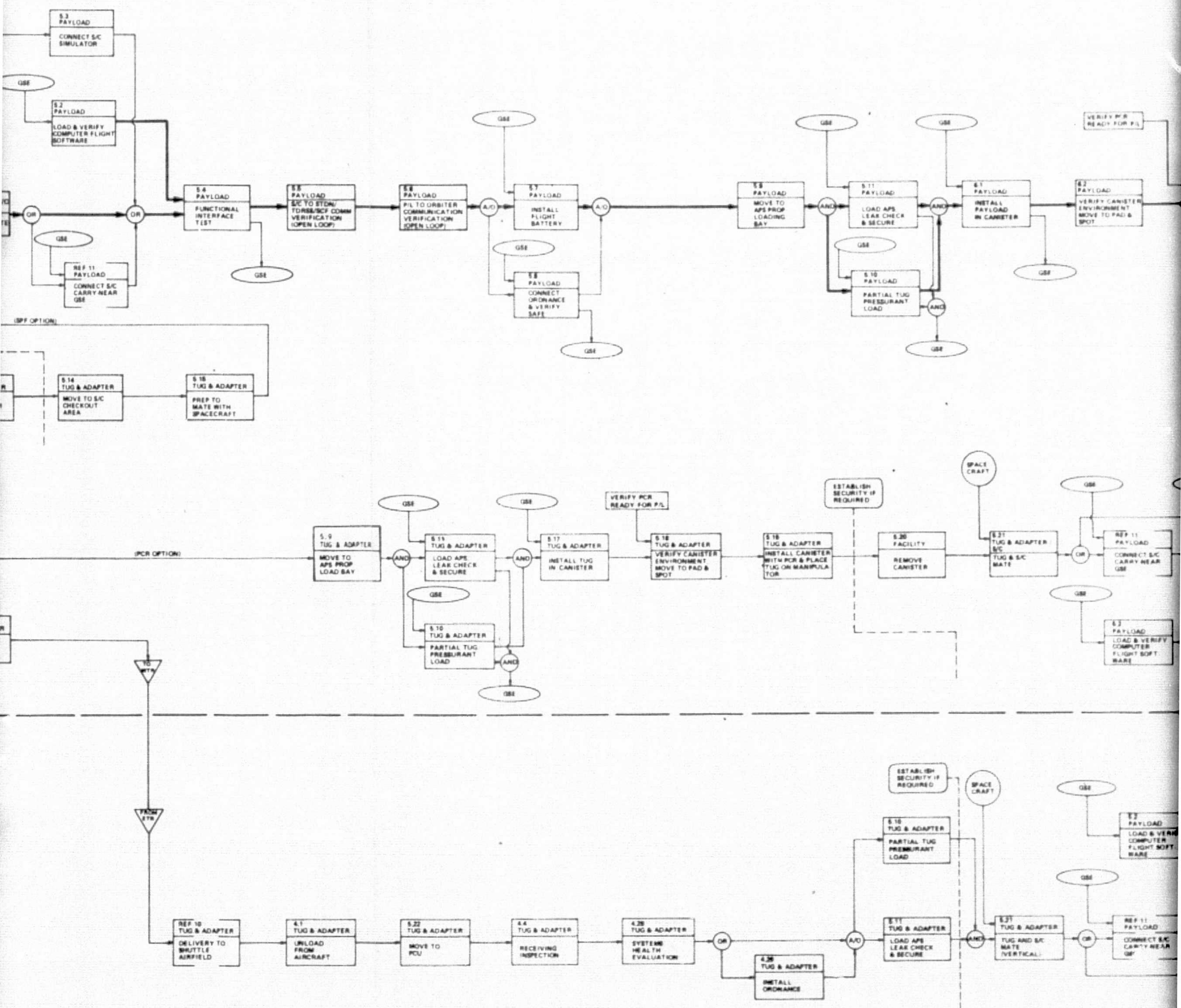

FOLDOUT FRAME 5

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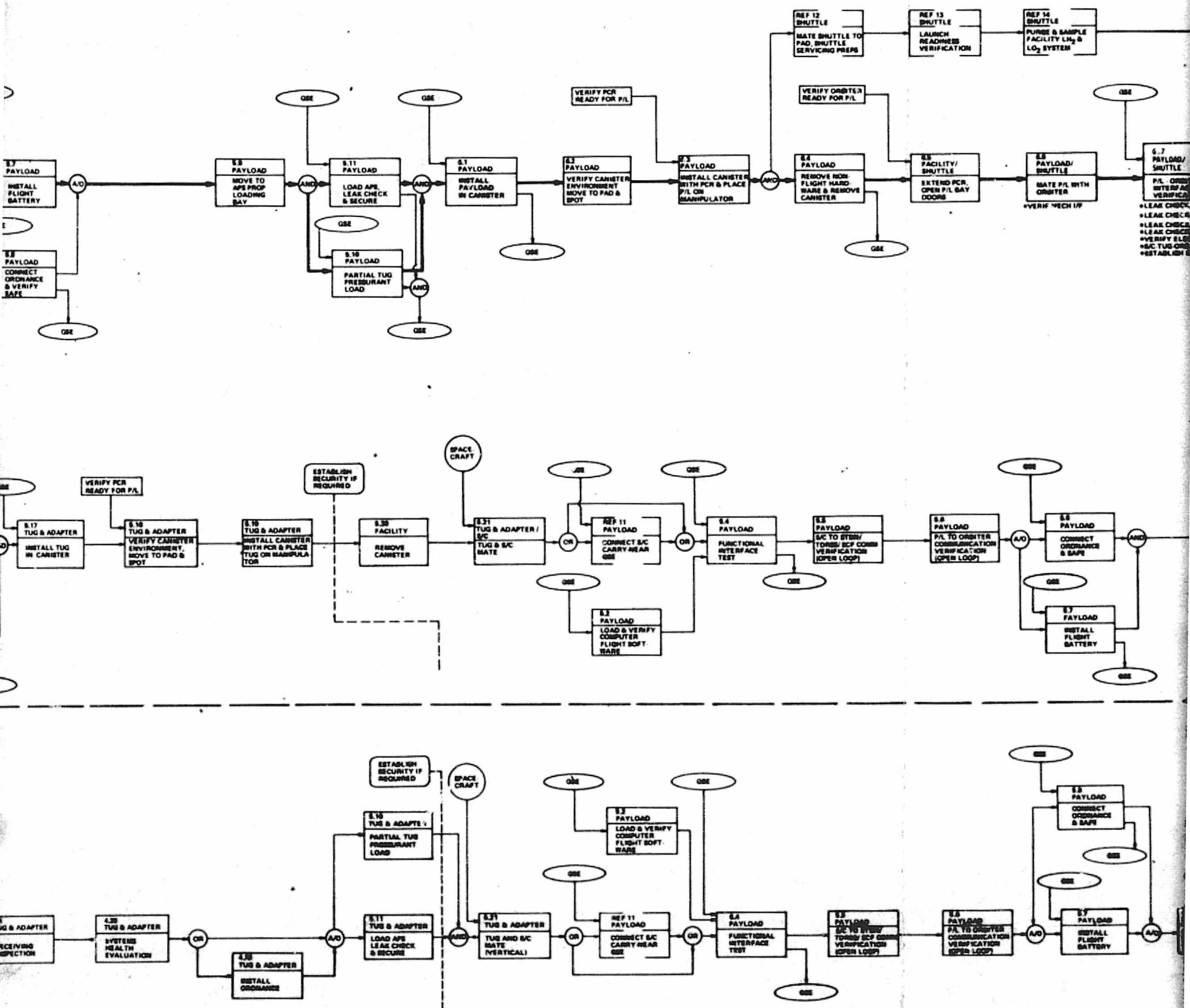

REF 12 SHUTTLE
MATE SHUTTLE TO PAD, SHUTTLE SERVICING PREPS
REF 13 SHUTTLE
LAUNCH READINESS VERIFICATION
REF 14 SHUTTLE
PURGE & SAMPLE FACILITY LH2 & LO2 SYSTEM
GSE
6.7 PAYLOAD
INSTALL FLIGHT BATTERY
A/O
5.9 PAYLOAD
MOVE TO APS PROP LOADING BAY
AND
5.11 PAYLOAD
LOAD APS, LEAK CHECK & SECURE
5.10 PAYLOAD
PARTIAL TUG PRESSURANT LOAD
6.1 PAYLOAD
INSTALL PAYLOAD IN CANISTER
6.2 PAYLOAD
VERIFY CANISTER ENVIRONMENT MOVE TO PAD & SPOT
VERIFY PCR READY FOR P/L
6.3 PAYLOAD
INSTALL CANISTER WITH PCR & PLACE P/L ON MANIPULATOR
6.4 PAYLOAD
REMOVE NON-FLIGHT HARDWARE & REMOVE CANISTER
VERIFY ORBITER READY FOR P/L
6.5 FACILITY/ SHUTTLE
EXTEND PCR, OPEN P/L BAY DOORS
6.6 PAYLOAD/ SHUTTLE
MATE P/L WITH ORBITER
•VERIF MECH I/F
6.7 PAYLOAD/ SHUTTLE
PAYLOAD
CONNECT ORDNANCE & VERIFY SAFE
5.17 TUG & ADAPTER
INSTALL TUG IN CANISTER
VERIFY PCR READY FOR P/L
5.18 TUG & ADAPTER
VERIFY CANISTER ENVIRONMENT, MOVE TO PAD & SPOT
5.19 TUG & ADAPTER
INSTALL CANISTER WITH PCR & PLACE TUG ON MANIPULATOR
ESTABLISH SECURITY IF REQUIRED
5.20 FACILITY
REMOVE CANISTER
SPACE CRAFT
5.21 TUG & ADAPTER / S/C
TUG & S/C MATE
OR
REF 11 PAYLOAD
CONNECT S/C CARRY-NEAR GSE
9.4 PAYLOAD
FUNCTIONAL INTERFACE TEST
9.2 PAYLOAD
LOAD & VERIFY COMPUTER FLIGHT SOFTWARE
9.5 PAYLOAD
S/C TO STDN/ TDRSS/ SCF COMM VERIFICATION (OPEN LOOP)
9.6 PAYLOAD
P/L TO ORBITER COMMUNICATION VERIFICATION (OPEN LOOP)
9.8 PAYLOAD
CONNECT ORDNANCE & SAFE
9.7 PAYLOAD
INSTALL FLIGHT BATTERY
TUG & ADAPTER
RECEIVING INSPECTION
4.20 TUG & ADAPTER
SYSTEMS HEALTH EVALUATION
4.18 TUG & ADAPTER
INSTALL ORDNANCE
5.10 TUG & ADAPTER
PARTIAL TUG PRESSURANT LOAD
5.11 TUG & ADAPTER
LOAD APS LEAK CHECK & SECURE
5.21 TUG & ADAPTER
TUG AND S/C MATE (VERTICAL)
9.2 PAYLOAD
LOAD & VERIFY COMPUTER FLIGHT SOFTWARE
REF 11 PAYLOAD
CONNECT S/C CARRY-NEAR GSE
9.4 PAYLOAD
FUNCTIONAL INTERFACE TEST
9.5 PAYLOAD
S/C TO STDN/ TDRSS/ SCF COMM VERIFICATION (OPEN LOOP)
9.6 PAYLOAD
P/L TO ORBITER COMMUNICATION VERIFICATION (OPEN LOOP)
9.8 PAYLOAD
CONNECT ORDNANCE & SAFE
9.7 PAYLOAD
INSTALL FLIGHT BATTERY

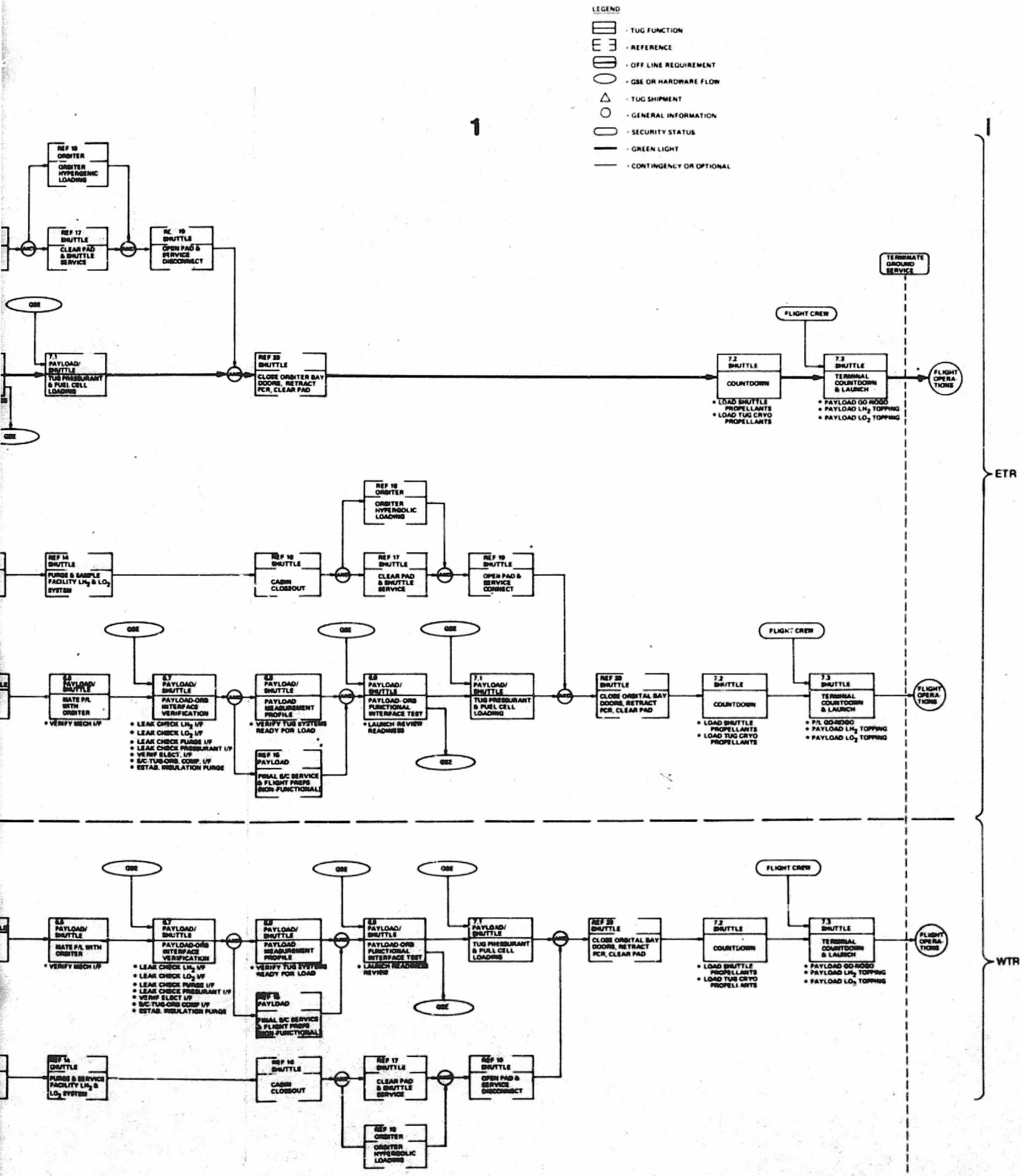


Figure III-A-2 Tug Ground Operations Functional Flow Diagram, 100K Clean Processing

FOLDOUT FRAME 2

block number that refers both to a top level flow and WBS category and provides a cross reference to the Function Description Data Sheet, GSE Requirements Specification Data Sheet, Maintenance Requirements Data Sheet, and Software Requirements Data Sheet contained in the appendixes. A Tug Functional Description Data Sheet has been prepared for each functional block of the flow diagram. Since these sheets are so voluminous, we have included them in Appendix A rather than in this plan.

3.1.1 Operations - Figure III-A-3 provides a brief summary of the operations derived from the functional flow analysis.

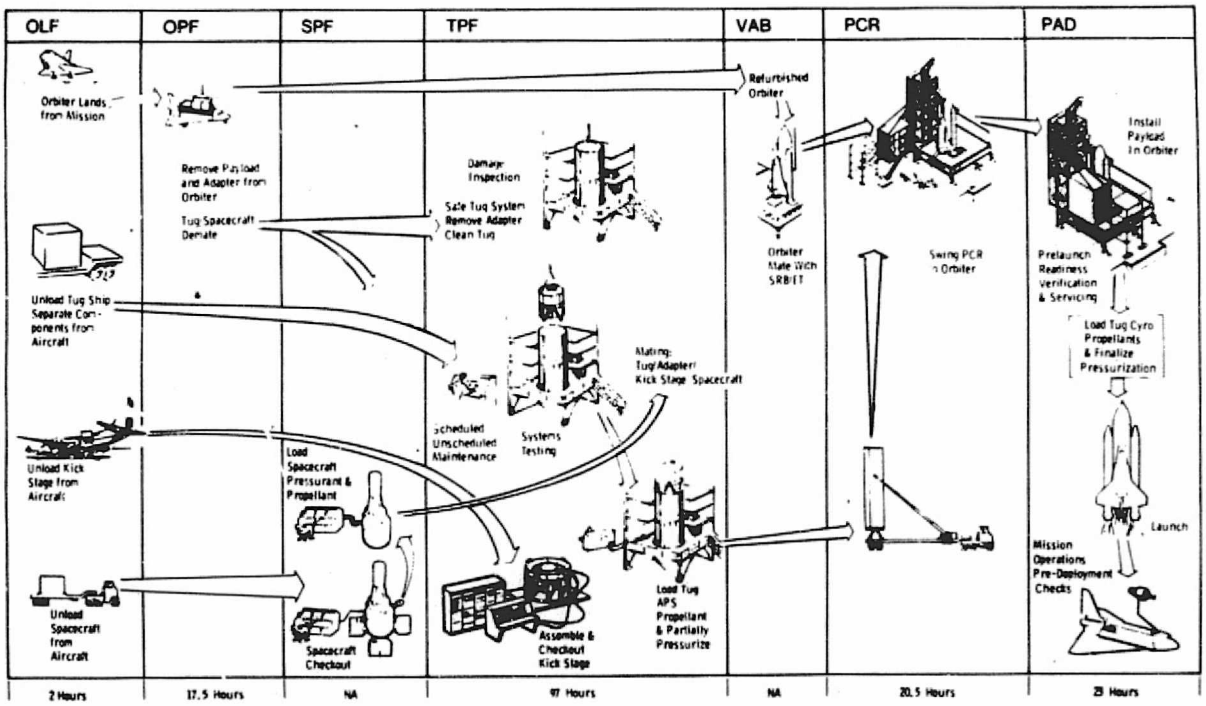


Figure III-A-3 Tug Ground Operations Flow

The Tug is transported to the OLF from the factory in a horizontal position via aircraft. It remains in the horizontal position while it is being transported to the test and checkout area; at ETR this is the TPF and at WTR the PPR. In the checkout area, the Tug is installed vertically into the checkout fixture where receiving inspection is performed, and ship-loose equipment is installed. The Tug remains in a vertical position throughout the remaining checkout process.

Upon completion of system level leak checks the Tug is cleaned and moved into 100K clean checkout area. The Tug is then mission-configured, which consists of avionics equipment changeout and configuring MSS/PSS console for an assigned mission. The deployment adapter is installed. If required, the kick stage is mated and the Tug is prepared for the System Health Evaluation (SHE) test. The SHE is performed, using the onboard checkout system in conjunction with the LPS. This test verifies the functional operation and operational compatibility of all Tug systems functioning together in the anticipated mission sequence; also it generates data used to compare with preestablished trend data.

Previous to, or concurrently with, these operations, the kick stage has been unloaded from the aircraft and transported to the checkout area. It is then rotated from its horizontal transportation position to the vertical and placed in the checkout fixture for build-up and checkout. Upon completion of systems checkout, a Combined Systems Test (CST) is performed. The kick stage may then be stored or mated with the Tug depending upon mission requirements. After Tug/kick stage interface verification, a SHE test is performed on the Tug/kick stage/adapter.

The Tug is then mated with the spacecraft in the vertical position. After mating the Tug/spacecraft interfaces are verified and the payload prepared for Functional Interface Test (FIT). FIT is a compressed-time simulated mission sequence to verify total payload functional and operational compatibility. The LPS will be used for functional stimulation, data monitoring, and recording.

Upon completion of this test, an open loop communication test between the payload to ground station and payload to Orbiter will be conducted. At this time the Tug flight battery will be installed and, if required, the ordnance will be connected. The payload is then loaded into the canister vertically, moved to the pad, and installed in the Payload Changeout Room (PCR). Figure III-A-4 illustrates the mate/demate process.

When the Orbiter is ready for payload mate, the PCR is mated to the Orbiter, the PCR and Orbiter doors opened, and the payload installed in and mated to the Orbiter. Interface tests are then performed, fuel cell reactants and remaining pressurants loaded, and at T-2 hours, MPS propellants loaded concurrent with Shuttle cryogenic propellent loading. The Tug is then ready for final countdown, launch, and mission operations.

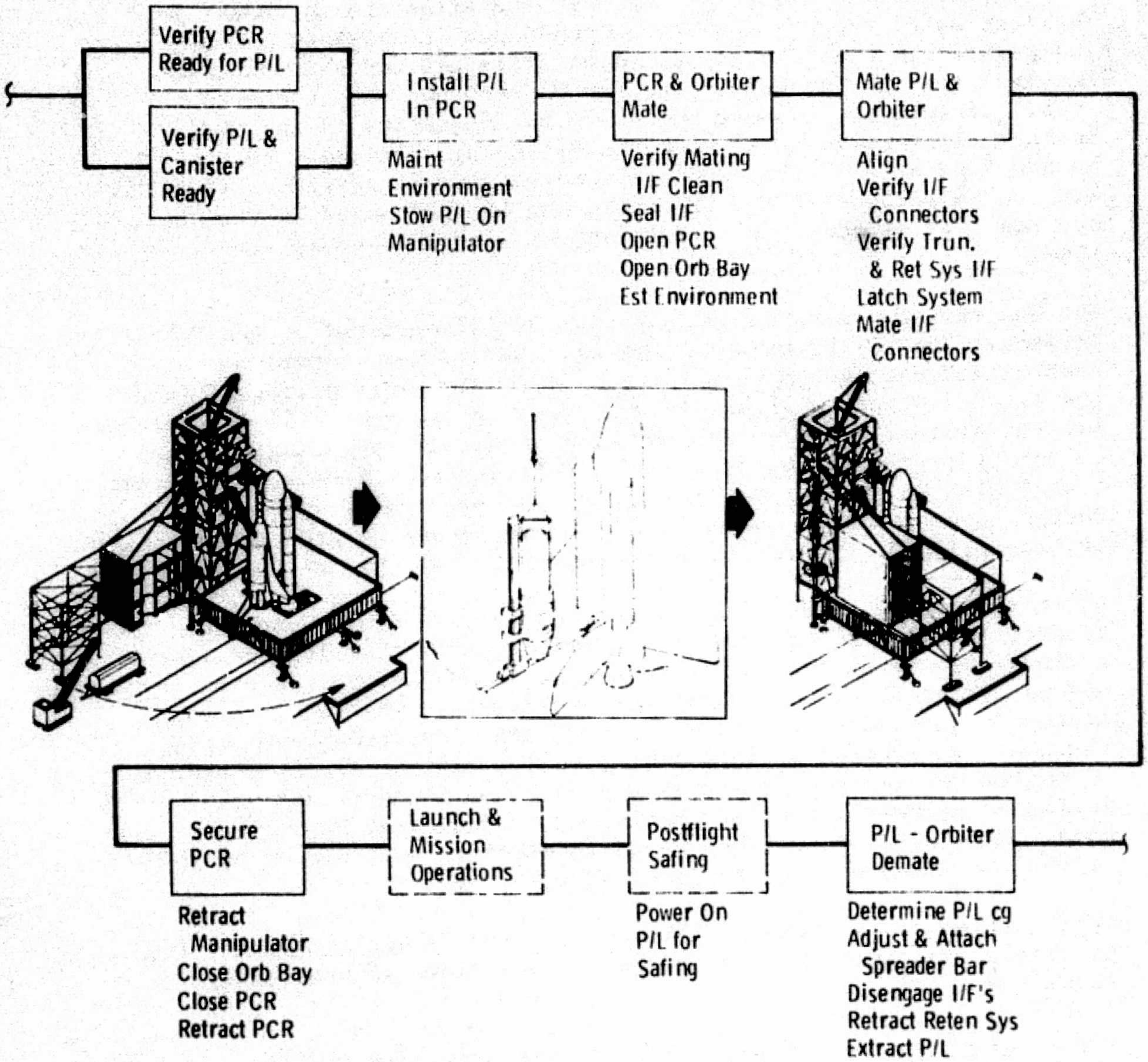


Figure III-A-4 Tug/Shuttle Mate and Demate

Upon mission completion and after the Orbiter lands, the flight crew will make a final check to ensure all Caution and Warning (C&W) are within limits before egress. The flight crew will initiate and verify the transfer of control of Tug functions to ground control. The Tug ground control will monitor the C&W parameters with particular attention to tank pressure levels during postlanding temperature variation. In the course of monitoring tank pressures and temperatures, ground control will verify the pressure integrity of all tanks in the gross terms available with flight instrumentation. These requirements will be accomplished at the OLF.

The Orbiter is then moved to the OPF, and after the cargo bay is verified safe, the bay doors are opened and the payload removed. The payload is then placed on a demate fixture and the spacecraft removed from the Tug before the Tug is returned to its checkout area. Since there is some concern with congestion in the OPF, another alternative is to move the mated Tug/spacecraft to the TPF before separation. The spacecraft could then be separated from the Tug in the airlock of the TPF. The Tug is then moved to the checkout area for maintenance, refurbishment, and turnaround verification.

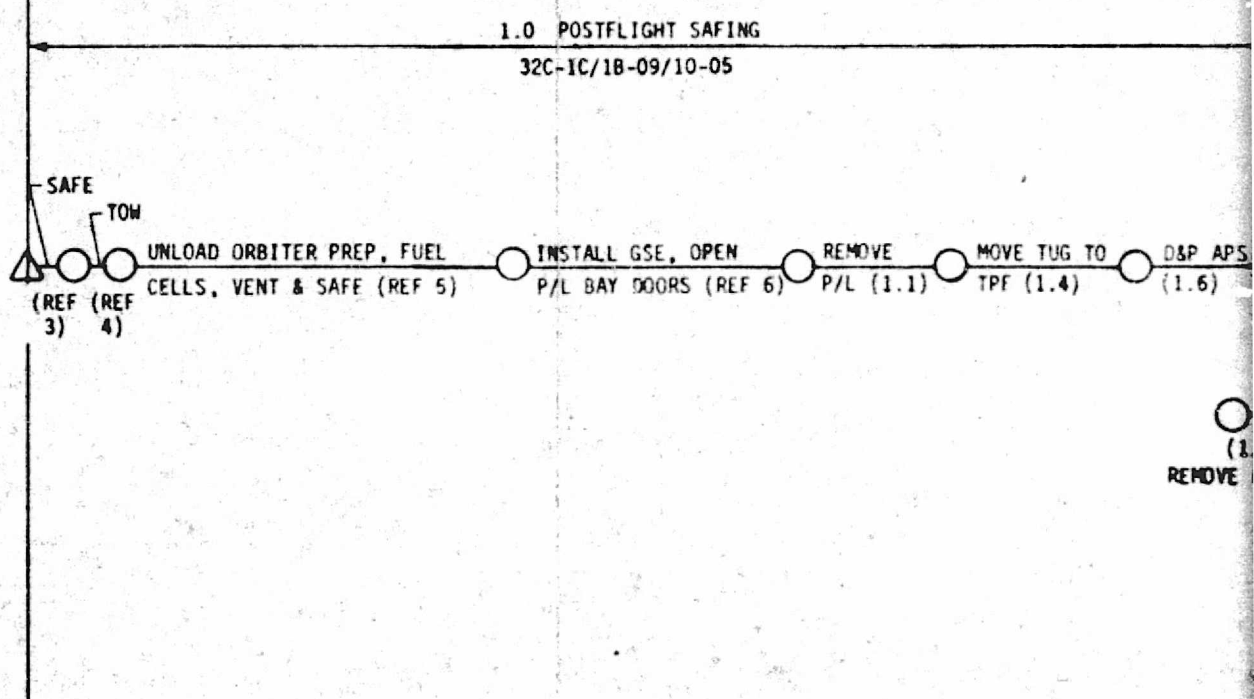
The Tug safing for turnaround operations is completed at the TPF airlock. The APS tanks and lines will be drained of residual hydrazine and the system purged and sealed with a dry nitrogen blanket. The flight battery will be disconnected and removed. All Tug pressurized systems will be leak checked at maximum operating pressure to verify system integrity. Upon completion of the leak check, each system will be vented to a pressure of one-fourth or less of the design burst pressure and sealed. The remainder of processing will be accomplished with the tanks locked up to this blanket pressure.

After the Tug is safed, the Tug and adapter are demated and the adapter is moved to its area for refurbishment. The Tug undergoes a visual damage inspection to determine if any damage has been incurred during flight or postflight operations. The Tug is then cleaned and moved to the clean area of TPF. Any troubleshooting that may be required by inflight anomalies will be accomplished. Scheduled maintenance on Tug systems is then accomplished based on estimated hardware life and condition, as indicated by inflight data. Any module that requires replacement by schedule or by inflight anomalies will be replaced at this time.

Upon completion of these activities, the Tug is configured for its particular assigned mission and the flow follows as previously described.

3.1.2 Stick-and-Ball Chart - The stick-and-ball chart (Fig. III-A-5), is a visual display of all functional, timeline, and resource requirements for the ETR "green light" flow. It provides timeline resource requirements for a single Tug turnaround. The chart provides function operational time by shift and by hour for two levels of functional flows and displays WBS allocations for turnaround operations. It also provides operations sequence data and indicates where parallel operations occur. The numbers and titles appearing between or at the circles, refer to block numbers on the Tug Ground Operations Functional Flow Diagram (Fig. III-A-2). The numbers appearing under GSE refer to the GSE unit identification numbers. Description sheets for each piece of GSE is included in Appendix B.

SHIFTS	1								2								3									
HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26



*INCLUDES FACILITY SUPPORT MANPOWER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
TOTAL MANPOWER *	24	24	24	24	24	24	24	24	12	12	12	12	12	12	12	12	30	30	30	30	26	26	26	29	17	21
TEST CONDUCTOR																										
TEST ENGINEER																	1	1	1	1	1	1	1	1	1	2
PROPULSION TECHNICIAN																								2	2	2
MECH/STRUCT/THERM TECH.																	4	4	4	4						
AVIONICS TECHNICIAN																										2
SAFETY ENGINEER																	1	1	1	1	1	1	1	1	1	1
QUALITY CONTROL TECH.																								1	1	2
TECHNICAL SUPPORT	8	8	8	8	8	8	8	8	3	3	3	3	3	3	3	3	8	8	8	8	8	8	8	8	3	3
MANAGEMENT SUPPORT	8	8	8	8	8	8	8	8	1	1	1	1	1	1	1	1	8	8	8	8	8	8	8	8	1	1

FACILITIES
FACILITY SUPPORT MANPOWER
1ST SHIFT 8 MEN
2ND SHIFT 8 MEN

OLF — ORBITER PROCESSING FACILITY (OPF)

GSE

H-018
H-024
H-025

H-024

A-001
A-008
P-011
P-016

H-

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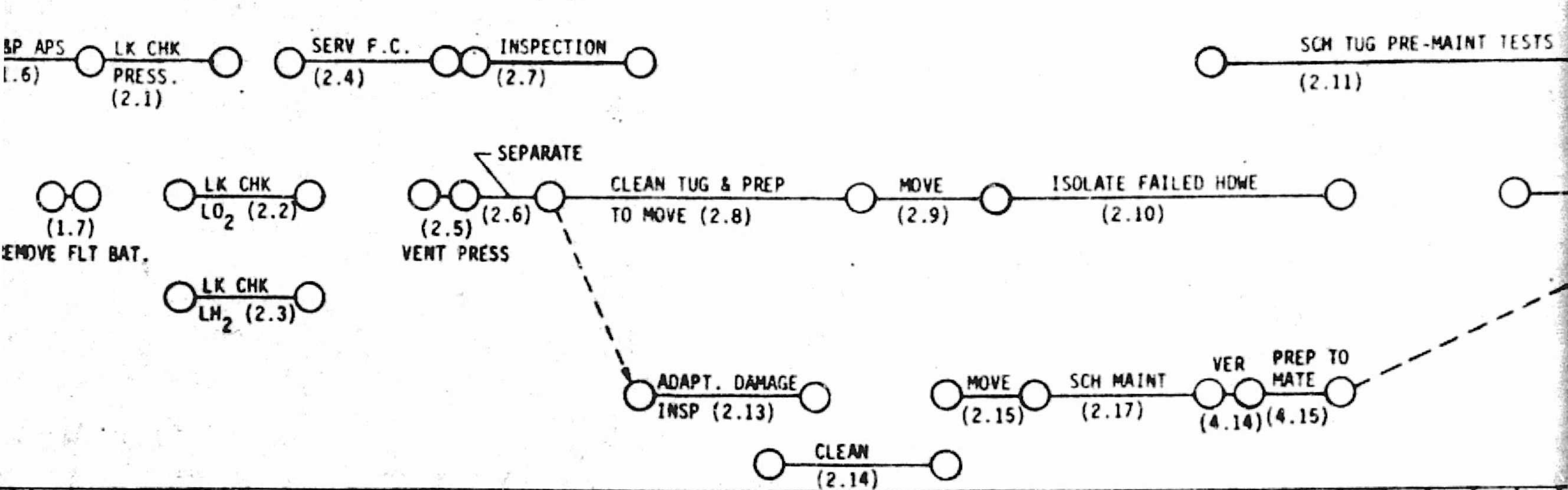
2.0 SCHEDULED MAINTENANCE & REFURBISH

32C-1C/1B-13/14-01



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TPF AIRLOCK AREA

A-001
A-008
P-011
P-016

P-011
P-016

P-016

P-002
P-003
P-004
P-005

H-009

A-001, A-002, A-003, A-00
A-007, A-008, A-009, A-01
A-011, P-016

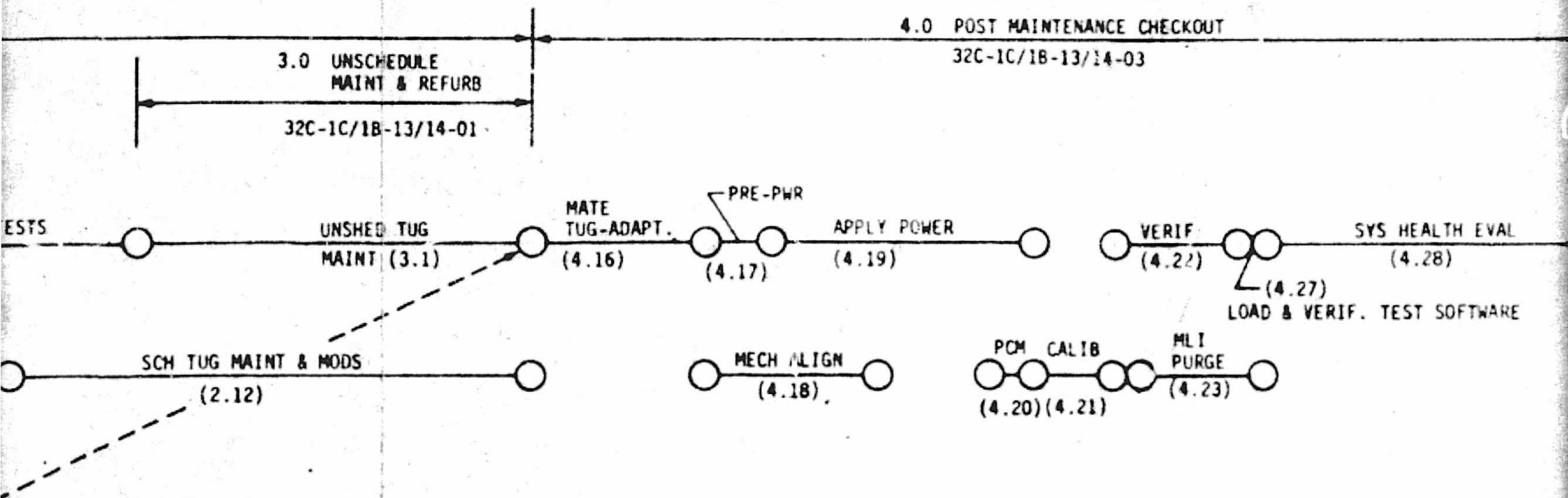
H-021

P-016, H-017, H-018, H-003, H-007

H-003
H-001, H-026

P-001
A-014, H-001
P-011, P-016

8					9								10								11								12						
60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95



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TUG PROCESSING FACILITY (TPF)

TPF CHECKOUT AREA

A-006,
A-010,

A-001, A-017
P-001, P-011
P-016

A-001
A-002
A-003
A-015

A-001

A-003

A-001, A-006, A-007, A-0
A-009, A-016

P-014, P-019, S-001, S-002

P-006 P-008

A-008
A-010
A-009 A-013

P-009, P-016

FOLDOUT FRAME 3

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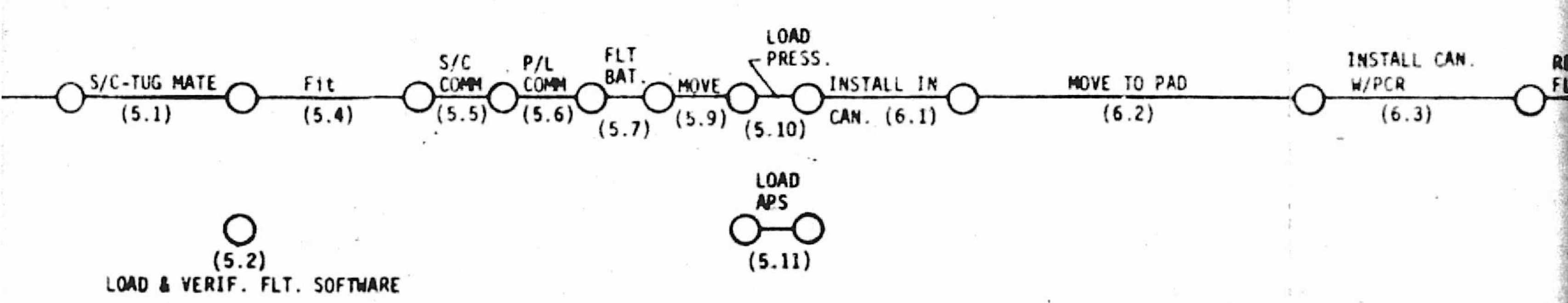
5.0 TUG/PAYLOAD MATING & CHECKOUT
32C-1C/18-13/14-04

6.0 TUG/SHUTTLE M
32C-1C/18-09



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PROP LOAD AREA

PAYLOAD CHECKOUT ROOM (PCR)

-008

A-001, A-017
P-008

A-001, A-008
A-009, A-011
A-012

A-001
A-008
A-009

A-001
A-006

A-001
A-006

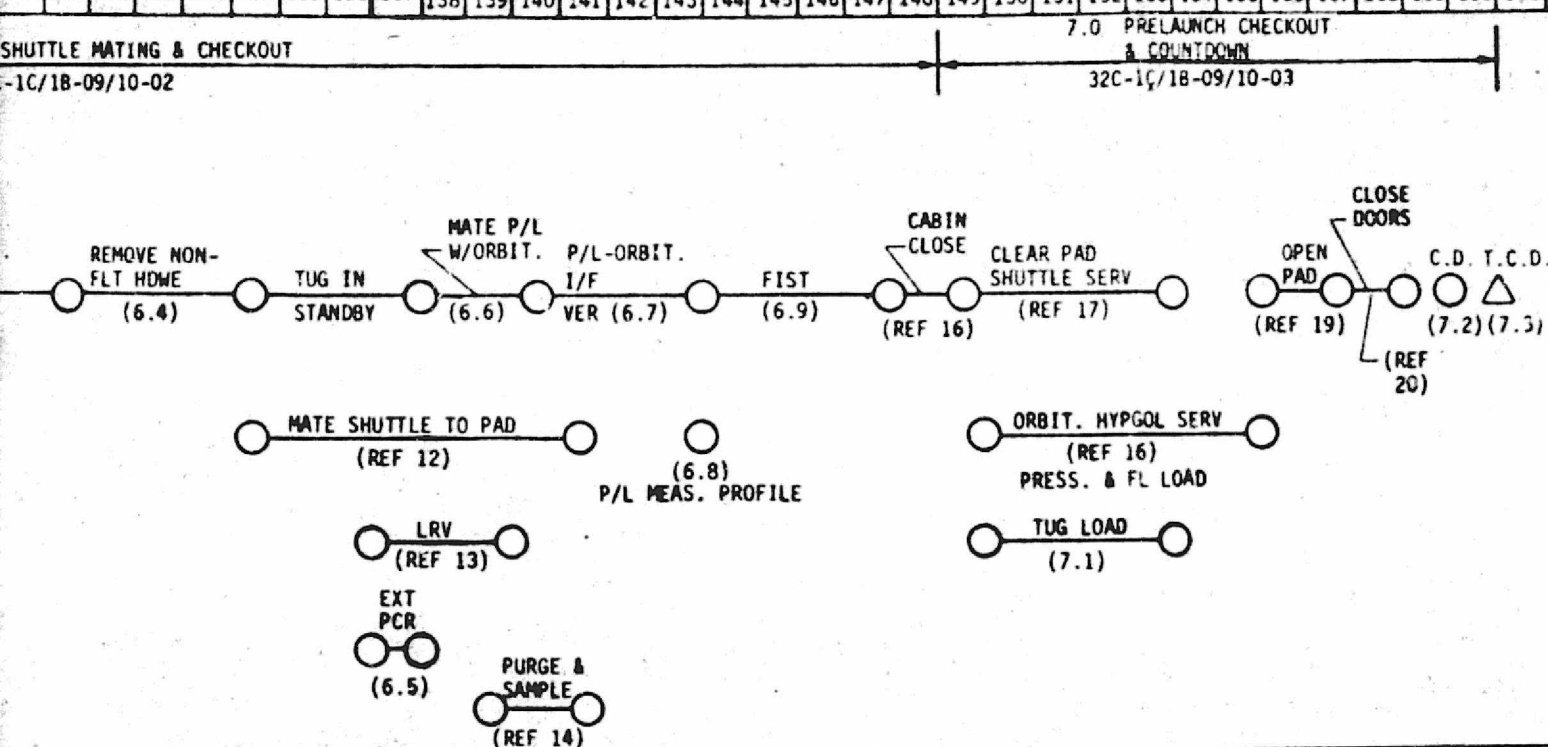
A-001
A-005
H-021

H-018
H-024
H-025

A-005
P-011
P-016

P-011
P-012
P-017
P-018

A-005, H-018



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LAUNCH PAD

R) | IN ORBITER

GFE ONLY REQUIRED TO SUPPORT TUG

Figure III-A-5 Tug Ground Operations Timeline Resource Requirements (KSC "Green-Light"

The manpower resources necessary to perform the sequenced functions are provided by type and skill. The facilities identified to support turnaround activities are identified, as they are used for a single Tug turnaround. The GSE necessary to support each function is shown and its use timelined.

3.1.3 Tug Turnaround Flow - The waterfall shown in Figure III-A-6 summarizes the KSC green light sequence shown on the Tug functional flow and highlighted by the heavy black interconnecting line. The operations time shown is an estimate of the time required by experienced personnel to complete the function. While the Tug itself does not require 160 hours for ground turnaround operations, the Tug flow has been fitted into the overall KSC Shuttle/Tug Turnaround Allocation dated June 21, 1974.

3.2 Facility and GSE Requirements

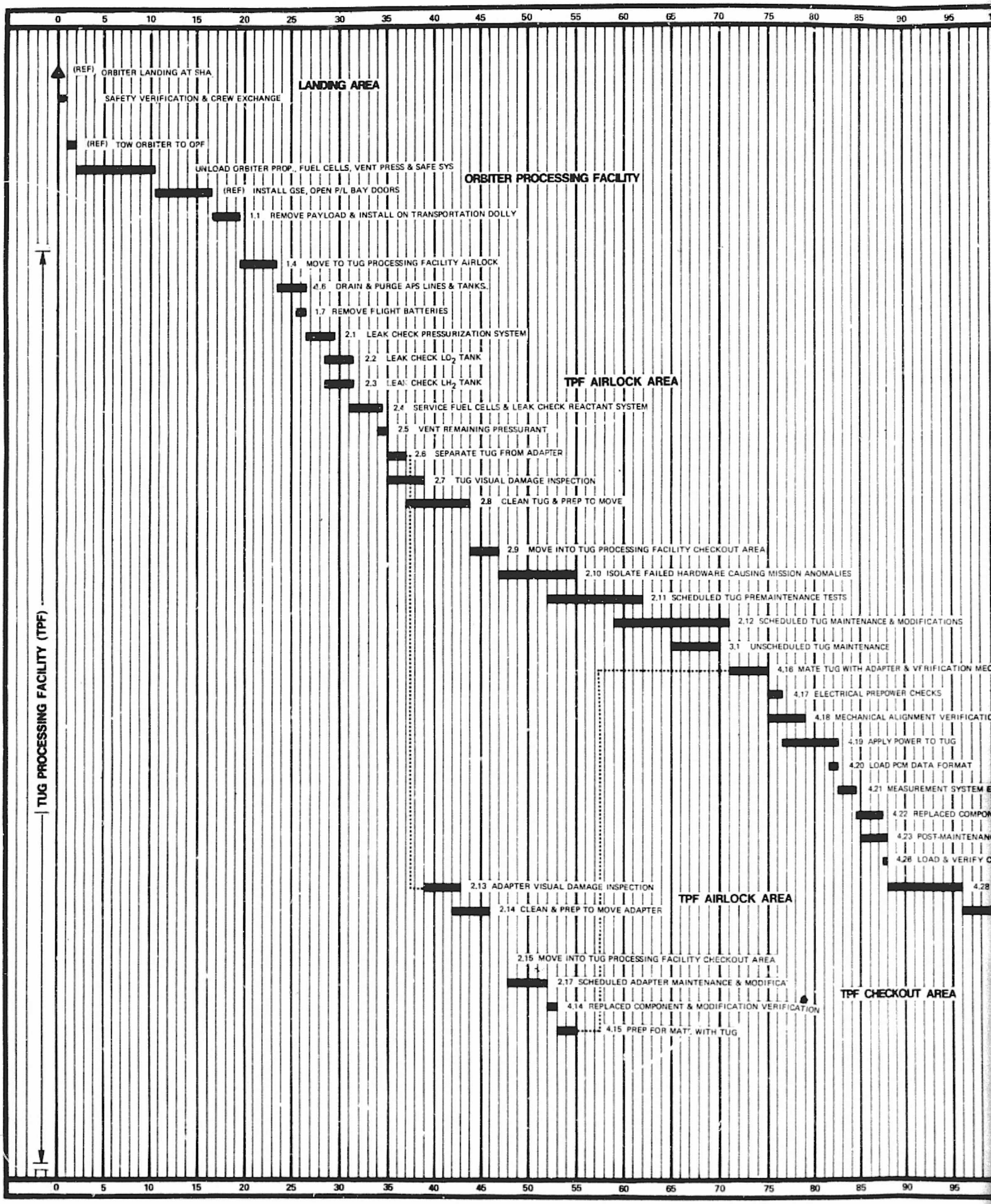
3.2.1 Facilities - The operational phase data was developed to reflect pure requirements for facilities and GSE. Subplan D assesses existing and planned facilities for compatibility with the operational phase requirements, and facility selections will be made at that time. In order to develop green light flows, we have defined generic facilities such as a Tug Processing Facility (TPF) without specifically defining which existing facility will be used. Table III-A-1 summarizes the facilities that are required. Appendix C provides detailed facility requirement sheets.

3.2.2 GSE Requirements - The GSE requirements for ETR and WTR are summarized in Table III-A-2 and are identified in detail in Appendix B. GSE identified has been restricted to significant items related directly to Tug ground operations. No attempt was made to itemize hand, power, and machine tools required in the maintenance shops or any standard items. GSE identification numbers refer to the requirement description sheets in Appendix B.

The LPS concept for centralized automatic checkout and monitoring of the Tug was used at both launch sites. It was assumed I/O equipment dedicated to Tug usage will be available for maintenance and checkout and that the LPS will supply hardware interface modules to meet Tug requirements.

3.3 Transportation Requirements and Support

3.3.1 Mode of Transportation - We have looked at the major transportation and handling requirement associated with the Tug ground operations functional flow based on the size and weight of the Tug described in the Baseline Space Tug Configuration Definition, MSFC 68M00039-2. Mode of transportation, transportation support equipment (TSE), and functional support activities, were assessed against:



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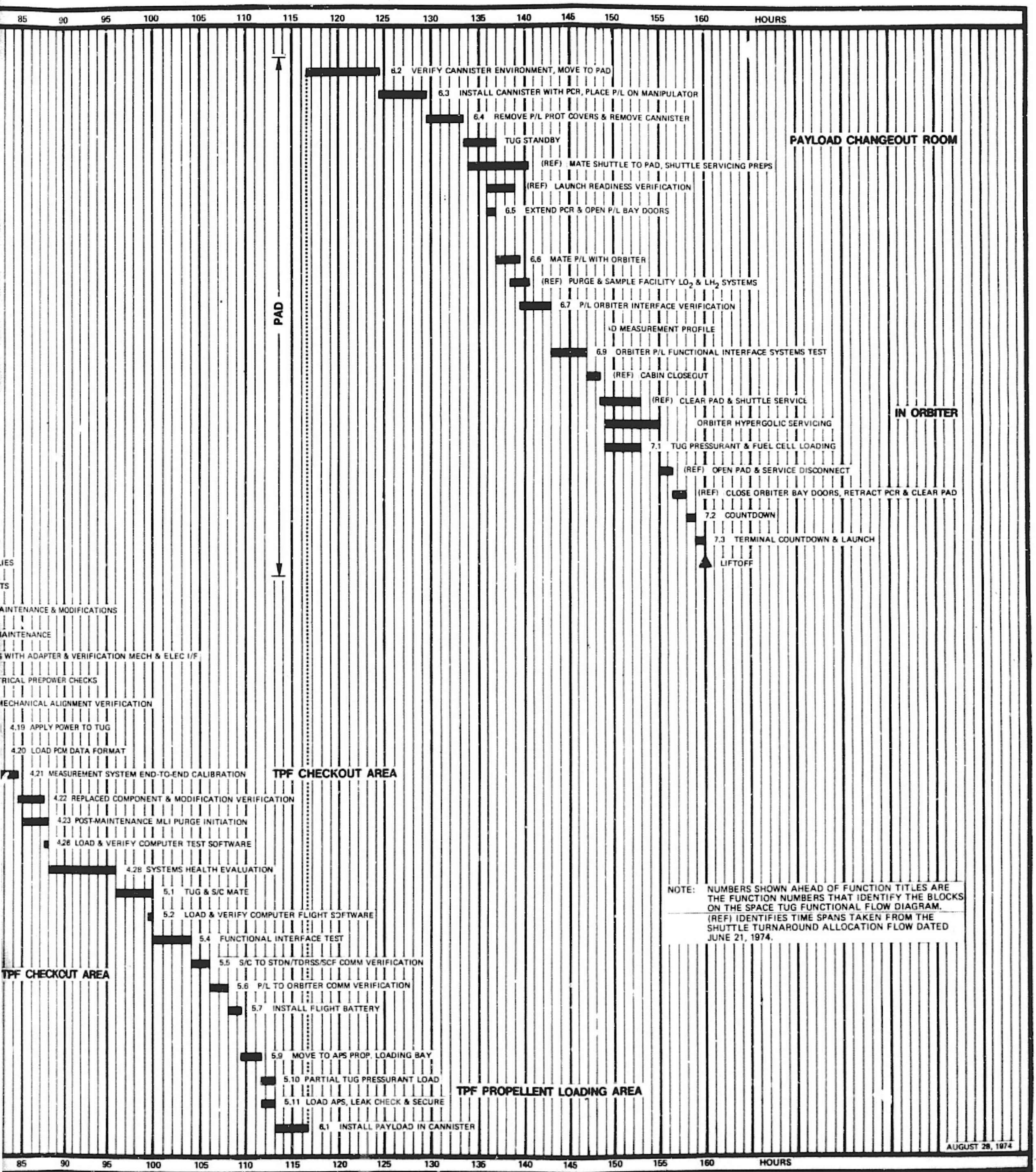

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Figure III-A-6 Tug Turnaround Flow

Table III-A-1 Facility Requirements

Facility	Functions	Facility Requirements
Orbiter Processing Facility (OPF) (Transfer Aisle)	Offload Payload from Orbiter	Existing Transfer Aisle
OPF (Tug Demate Area)	Demate Tug/Spacecraft Remove COMSEC equipment	Single Cell Located in OPF, Controlled Access, LPS Terminal
Tug Processing Facility (TPF) (Airlock)	Receive, Inspect, Damage Inspection, Tug safing, Cleaning, Demate Tug/ Adapter	Controlled Access Area, MPS and APS Purge and Vent Provisions, Personnel Safety Provisions, LPS Terminal, 100K* Class Clean Room
TPF (Tug Maintenance and Checkout Area)	Tug Refurbish, Checkout and Buildup for Mission Mate Spacecraft to Tug and Checkout	Two Bay, Controlled Access, *100K Clean Room, Tempest Compatible, Parasitic Antenna, LPS Terminal OIS Communications
TPF (Deployment Adapter Maintenance and Checkout Area)	Deployment Adapter Refurbish and Checkout in Preparation for Mate with Tug	Two Bay, *100K Clean Room, OIS Communication, LPS Terminal
TPF (Kick Stage Buildup and Checkout Area)	Kick Stage Buildup and Check in Preparation for Mission	Single Bay, *100K Clean Room, OIS Communications, LPS Terminal
TPF (Storable Propellant Loading Area)	Load Tug APS Propellants and Partial Pressurant Load	Single Bay, *100K Clean Room, OIS Communications, LPS Terminal, Controlled Access, Personnel Safety Provisions
TPF (Tug and Adapter Storage Area)	Store Tug and Adapter until Required for Mission	Temperature and Humidity Controlled Area for Storing Four Tugs and Two Adapters
TPF (Tug Hardware Bonded St[illegible]ge Area)	Store Tug System Hardware Until Required to Support Refurbishment Activities	Temperature and Humidity Controlled Storage Area, Storage Racks, Bins, Shelves for Tug Components

* 100K was baseline;
factory clean is the study recommendation

Table III-A-1 (concl)

TPF (Engine Preparation and Service Area)	Major Engine Overhaul and Refurbishment	Controlled Access*100K Clean Room, LPS Terminal
TPF (Battery/Fuel Cell Service Area)	Battery and Fuel Cell Preparation and Refurbish	Controlled Access*100K Clean Room, LPS Terminal, Hydrogen and Oxygen Vents
TPF (GSE Checkout and Maintenance)	Periodic Calibration and Maintenance of GSE	*100K Clean Room, Bench Calibration Areas
TPF (Avionics Checkout and Maintenance)	Avionic LRU Refurbishment and Checkout	*100K Clean Room, LPS Terminal, Stable Platform for Optical Alignment, LRU Refurbishment Area
TPF (Paint Shop)	Refurbish Tug LRU/Segments	*100K Compatible
TPF (Canister Load Area)	Load Payload into Canister for Transport	*100K Clean Area, Controlled Access, OIS Communication
Payload Changeout Room	Payload Transfer (Canister to PCR), Buildup and Checkout, Transfer (PCR to Orbiter Bay)	Retractable 100K Clean Room, LPS Terminal, Payload Handling Device, Controlled Access, Tempest Compatible

Table III-A-2 Ground Support Equipment Matrix

ID No.	Nomenclature Avionics	OPF		TPF						
		Transfer Aisle	Tug Demate	Airlock	Tug Maint & C/O Area	Adapter Maint & C/O	KS Buildup & C/O	Propellant Load	Offline Support	WTR
A-001	Electrical Power Supply		x	x	x		x			x
A-002	Electrical Power Test Set				x		x			
A-003	Electrical Load Banks				x		x			
A-004	Battery Test Set								x	
A-005	Battery Charger				x					x
A-006	Communication Test and Checkout Equipment				x		x			
A-007	Guidance and Navigation Test and Checkout Equipment				x		x			
A-008	Control and Data Acquisition Console			x	x		x			x
A-009	Memory Load and Verify Unit				x		x			x
A-010	Electronics Calibration Equipment				x					
A-011	Orbiter Cable Simulator				x					x
A-012	Umbilical Simulator				x					x
A-013	Star Sensor Simulator				x		x			
A-014	Tug/Spacecraft Simulator					x				
A-015	Fuel Cell Dummy Load Unit								x	
A-016	Ordnance Event Verification Cables				x					x
A-017	Latch Mechanism Test Set				x					
A-018	Hardware Interface Module (HIM)				x					x

Table III-A-2 (cont)

ID No.	Handling and Transportation	Transfer Aisle	Tug Demate	Airlock	Tug Maint & C/O Area	Adapter Maint & C/O	KS Buildup & C/O	Propellant Load	Offline Support	WTR
H-001	Tug Workstand			x	x					x
H-002	Engine Workstand								x	
H-003	Deployment Adapter Workstand			x		x				
H-004	Tug Transportation Dolly			x	x					
H-005	Cargo Bay Work Platform Set	x								x
H-006	Internal Platform			x	x					
H-007	Deployment Adapter Dolly			x						
H-008	Deployment Adapter Protective Cover Kit								x	
H-009	Spacecraft Adapter Transport/ Storage Pallet			x	x					
H-010	Kick Stage Protective Cover Kit			x						
H-011	Kick Stage Motor Cradle			x						
H-012	Kick Stage Buildup/Checkout Fixture						x			
H-013	Kick Stage SRM Storage Pallet								x	
H-014	Kick Stage Storage Pallet								x	
H-015	Tug Storage Pallet								x	
H-016	Tug Engine Handling Kit								x	
H-017	Deployment Adapter Storage Pallet								x	
H-018	Handling Sling Kit	x		x	x		x			x
H-019	Tug Protective Cover Kit		x							x
H-020	Tug Desiccant Kit								x	
H-021	Battery Handling Kit			x	x					x
H-022	Air Carry Tie Down Kit								x	x
H-023	Transport Data Recorder								x	
H-024	Tug Transtainer	x		x	x					x
H-025	Tug Lifcing Rings	x		x	x					x
H-026	Inspection Workstands		x	x	x					x
H-027	Spacecraft Docking Simulator				x					
H-028	Kick Stage Transtainer						x			
H-029	Vertical Adapter									x
H-030	Kick Stage Motor Support Fixture			x						

Table III-A-2 (concl)

ID No.	Propulsion and Mechanical	Transfer Aisle	Tug Demate	Airlock	Tug Maint & C/O Area	Adapter Maint & C/O	KS Buildup & C/O	Propellant Load	Offline Support	WTR
P-001	Aft Umbilical Servicing Unit								x	x
P-002	Fuel Cell GN_2 Purge Unit			x						x
P-003	Fuel Cell Water Supply Unit								x	
P-004	Fuel Cell GH_2 Accumulator Charge Unit								x	
P-005	Fuel Cell GO_2 Accumulator Charge Unit								x	
P-006	Engine Alignment Kit				x					
P-007	Tug Engine Actuator Servicing Kit								x	
P-008	Alignment Kit				x					
P-009	Insulation Purge and Metering Unit			x	x				x	x
P-010	Propellant Supply and Transfer Unit								x	
P-011	APS Propellant Control Set			x	x		x	x		x
P-012	APS Propellant Supply and Transfer Unit								x	x
P-013	Preservation Unit								x	
P-014	Vacuum Pump and Gauge Unit				x					
P-015	Hydraulic Servicer				x					
P-016	Pressurization Control Set			x	x	x		x		x
P-017	Decontamination Unit APS								x	
P-018	Vacuum Pump and Gauge Unit APS							x		x
P-019	Thermal Control Servicing Set					x				
P-020	Hot GN_2 Purge Unit					x				
	<u>Structural</u>									
S-001	Ultrasonic Scan Unit					x				
S-002	Radiography Unit					x				

1) Tug transportation between KSC and WTR;

2) Tug transportation from manufacturere to KSC;

3) Normal ground movement at KSC.

Air transportation was selected as the primary mode of transport assuming that the 747 approach is used for the Orbiter and that it is available to Tug. The outsized configuration of Tug precludes over-the-highway transport because of restricted travel times, route survey requirements, special routing, permit acquisition, escort and security control, and added time in transport. Water mode is not practical based on shipping time and the possibility of shipment from an inland manufacturer, although it should still be considered as a viable alternative if the recommended approach is not acceptable. Rail transportation is not desirable based on oversized configuration, excessive time enroute, possibility of unfavorable induced loads, and required combination of rail and water transportation to return Tugs from contingency landing sites. Air transport will accomplish one day delivery from a manufacturer to KSC or between KSC and WTR. Tugs can be flown from alternative or contingency landing sites to KSC in minimal time.

Several probable cargo aircraft were looked at for internal cargo transport of the Tug. Tug is too close to the maximum cargo envelope of the Pregnant- or Mini-Guppy to make transport with that aircraft desirable. Aero Spacelines Super Guppy could accommodate Tug but availability of that aircraft in the projected Shuttle time frame is questionable. Major modification to the Boeing 747 internal cargo structure would be required for normal transportation with that aircraft. Tug could be ferried within the Orbiter in the piggyback mode. This should add no significant design factors not already incorporated into the Orbiter payload bay design, but would require significant trade study relative to the added weight and airborne configuration of the Orbiter on the 747. An alternative approach, and the one we recommend, is the 747 piggyback shipment of the Tug in a cargo canister that occupies some portion of the envelope currently planned for the piggyback shipment of the External Tank. The envelope created by the 747 cargo canister would accommodate Tug/Spacecraft/Kick Stages for combined payload shipments. Besides providing maximum environmental protection and relative ease of handling, the cargo canister could be multiuse in nature, accommodating various payloads including Spacelab and support equipment shipments, and provide protective enclosure for payload movements during ground processing as, for example, when transporting from the TPF to the PCR at the launch pad.

3.3.2 Tug Transportation between KSC and WTR - A typical transportation flow from KSC to WTR would start with Tug preparation for piggyback shipment at the TPF. Tug openings will be sealed, flight instrumentation kit will be installed, and LH_2 tank forward dome cover will be attached. A prime mover will position a cargo canister transporter with canister attached through the TPF airlock into the high bay aisle area to a point where it can receive the Tug. The coffin-type cargo canister will be opened by removing its upper half with the TPF crane. The crane will then lift the Tug, move it to the cargo canister, and position it in the canister. After tiedown attachments have secured the Tug in the lower half of the canister on the transporter, the upper half of the canister will be reinstalled and bolted at the canister attachment flanges. The Tug, secured inside the cargo canister, will be towed to the Shuttle airfield.

We recommend use of the Mate-Demate Fixture (MDF), Figure III-A-7, planned for use on Orbiter piggyback loadings at Palmdale and Edwards AFB, to lift and position the cargo canister for attachment to the 747. Multiple use of this fixture is cost-effective and it is assumed the Palmdale and Edwards AFB units can be broken down and reassigned to WTR and KSC in time to support Tug operations in 1983.

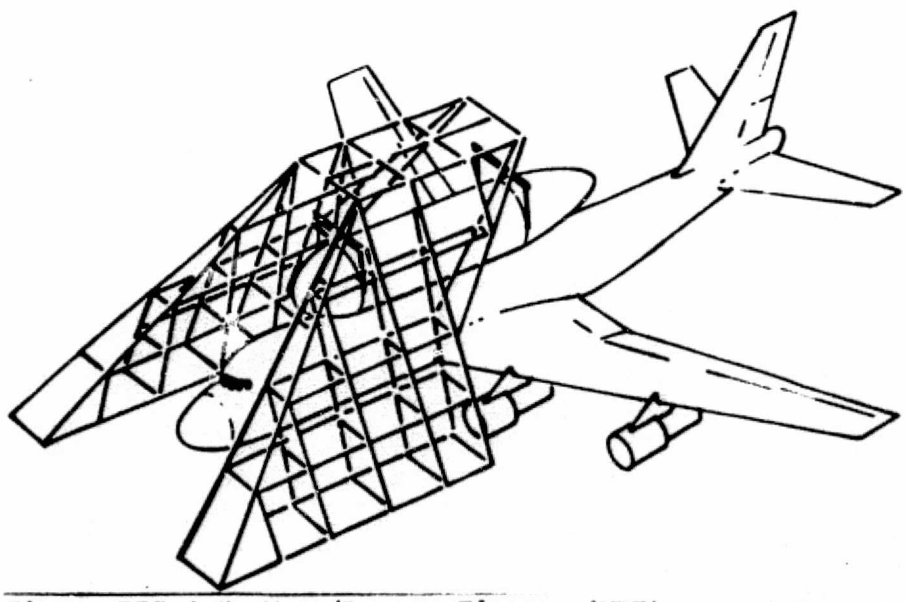


Figure III-A-7 Mate/Demate Fixture (MDF)

When the cargo canister transporter arrives at the Shuttle airfield, it will be towed into the MDF. The canister will be detached from the transporter and raised to position at the top of the MDF. The empty canister transporter will be towed out of the MDF. The 747 will then be towed into the MDF and the cargo canister will be attached to the aircraft. The 747 with piggyback cargo canister attached will be towed out of the MDF and to the airstrip for taxi and takeoff.

After landing at WTR, the 747 will taxi to proximity of that site's MDF. After engine shutdown and postflight checks, the 747 will be towed into the MDF. The cargo canister will be disconnected and lifted free of the aircraft, the aircraft will be towed out of the MDF, and the cargo canister transporter will be towed into the MDF. The canister will be lowered and attached to its transporter that will then be towed to the PCU.

3.3.3 Tug Transportation from Manufacturer to KSC - A contractor loading operation for Tug shipments from the manufacturer to KSC would be similar to that described for transportation from KSC to WTR, but a crane operation would probably be used at the airfield instead of the MDF unless additional procurement of that fixture can be proven cost-effective.

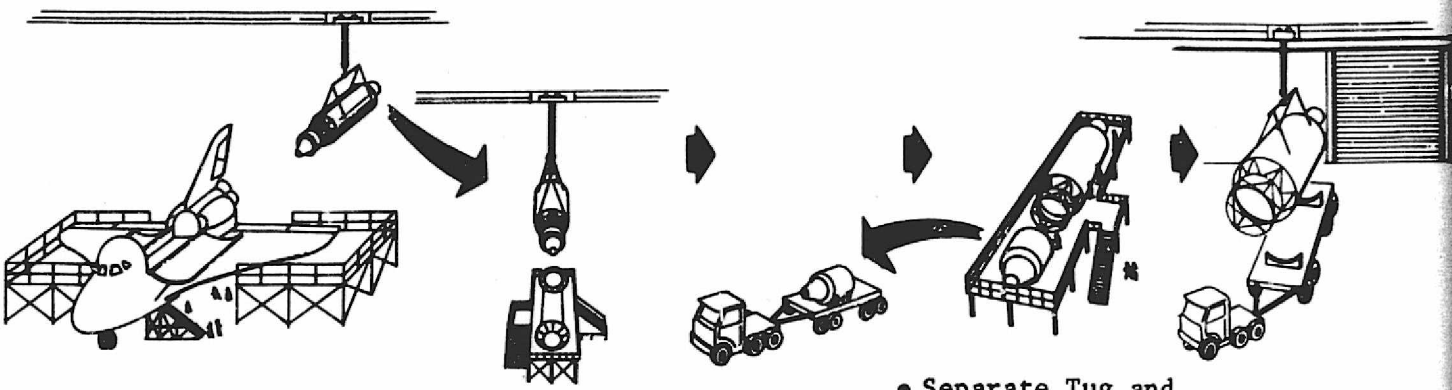
A summary of the major transportation support equipment required for the transportation concept presented is shown in Table III-A-3.

3.3.4 Normal Ground Movement at KSC - A summary of a normal ground operations handling flow, based on the green light function flow, is illustrated in Figure III-A-8. The flow will start with removal of the payload from the Orbiter payload bay at the OPF. The payload bay doors will be opened, the OPF bridge crane will be positioned, and hoisting sling attachment will be made at the payload. The payload will be detached from the payload bay, lifted free of the Orbiter, and placed on a payload demate fixture. The payload hoisting sling will be removed. The spacecraft will be detached from the Tug, and its lifting sling attachment will be completed. The spacecraft will be lifted from the demate fixture, positioned on a spacecraft transporter, and secured and covered for movement to the spacecraft processing facility. A Tug ground transporter will be towed by prime mover into position parallel with the demate fixture. Hoisting sling attachment will be made at the Tug, and the bridge crane will lift and position the Tug on its transporter. Tiedown will be completed, a Tug cover will be installed, and the Tug and adapter will be towed to the TPF.

Table III-A-3 TSE Requirements

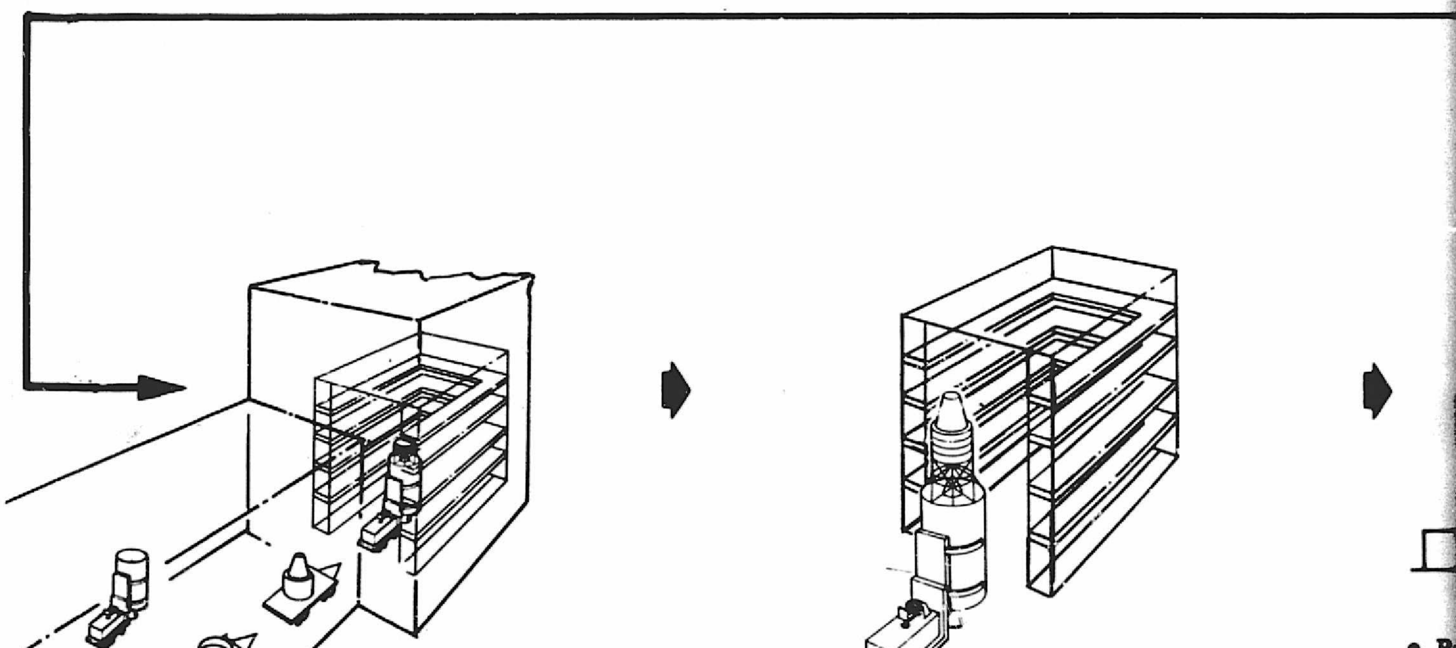
TSE Item	Function	Emphasis
Transportation Instrumentation Kit H-023	Used to monitor and record temperature, humidity, shock and vibration during ground handling and air transportation.	Prevent damage. Monitor and control conditions leading to possible damage.
Tank Breather Set H-020	Two units, one for the LH_2 tank and one for the LO_2 tank. Provide for free breathing of clean, dry air.	Prevent inadvertent implosion due to negative Δ pressure.
LH_2 Tank Dome Cover H-019	Provide environmental closure for open end of Tug.	Prevent damage to LH_2 tank dome.
Cargo Canister	Provides environmental shipping/handling container for Tug.	
Cargo Canister Transporter	Supports cargo canister during Tug loading/unloading operations. Used to transport Tug in canister from TPF to airfield and return.	Modular containment for handling. Maintain clean condition. Facilitate handling operations.
Prime Mover	Provides towing power and maneuvering capability. Euclid, M-1, or other.	
Canister to Transporter Tiedown Kit	Provides tools, fittings, gages, etc, necessary for canister to transporter attach/detach operations.	Modular containment and inventory of equipment necessary to handling operations.
Cargo Cansiter Assembly Kit	Provides tools, fittings, gages, seals, etc, necessary for canister upper half removal and installation.	
Tug Tiedown Kit H-022	Provides tools, fittings, etc, to tiedown or release Tug from cargo canister.	
Tug Lifting Sling Set	Provides forward/aft spreader beam/hoisting cable assemblies and drop cable assemblies/end fittings to mate with Tug lifting adapters.	
Tug Lifting Adapters	Interface fittings with Tug and lifting sling set.	
Mate-Demate Fixture (MDF)	Provides controlled lifting/positioning capability for cargo canister loading and unloading from 747.	Multiple use of Orbiter handling fixture with common application for cargo canister loading/unloading.
Cargo Canister Lifting Sling Set	Provides forward/aft spreader beam/hoisting cable assemblies and drop cable assemblies/end fittings to mate cargo canister with MDF cranes.	
Canister to 747 Attachment Kit	Provides tools, fittings, etc, to accomplish cargo canister mate to common Orbiter support arms on 747.	Use of common 747 ferry attach points.
MDF Air Transfer Support Kit*	Provides tools, fittings, shipping containers and adapters, etc, to accomplish MDF tear down, transfer, and reassembly of the MDF for alternative/contingency site use.	Depends on decision to use MDF rather than mobile cranes at alternative/contingency sites.
Tug Transporters/ Dollies*	Provide for interim storage and transport of Tug before cargo canister loading at alternative/ contingency sites.	
Mobile Cranes*	Provide lifting/positioning of Tug for cargo canister loading at alternative/contingency sites. Provides lifting/positioning of cargo canister in lieu of MDF.	

*Alternative Contingency Site TSE



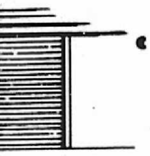
- Remove Payload from Orbiter Bay at OPF
- Place Payload On Demate Fixture

- Separate Tug and Payload On Demate Fixture
- Place Spacecraft on Spacecraft Transporter
- Place Tug On Ground Transporter

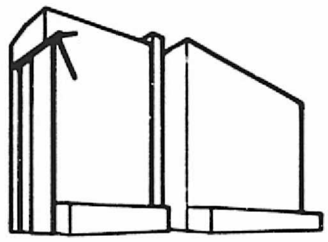


- Transfer and Install Refurbished Adapter
- Transfer and Install Kick Stage
- Transfer and Install Spacecraft
- Perform Interface Tests

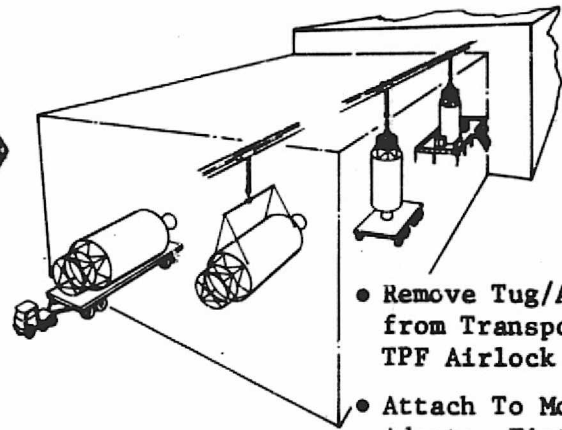
- Prepare Integrated Payload for Movement
- Remove Integrated Payload from Checkout Cell with Manipulator
- Transfer to Airlock Area



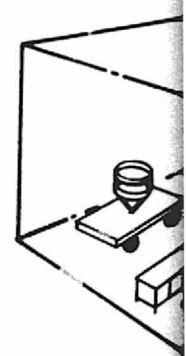
• Tow Spacecraft to Spacecraft Processing Facility

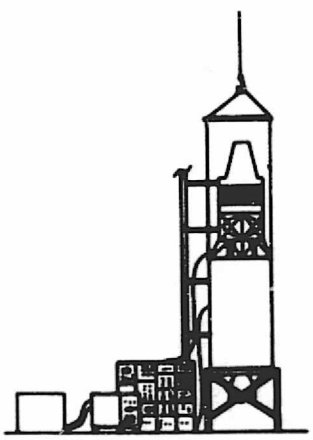


• Tow Tug/Adapter On Ground Transporter to TPF

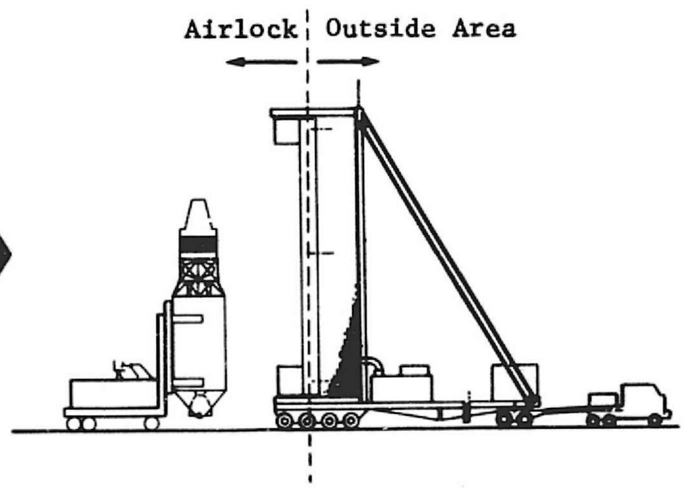


• Remove Tug/Adapter from Transporter In TPF Airlock Area
• Attach To Mobile Tug Adapter Fixture
• Pivot To Vertical Position
• Move To Airlock Precheckout Stand

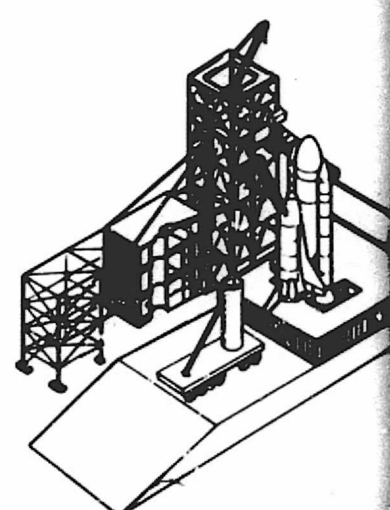




• Position Payload In Precheckout Stand
• Perform APS Loading

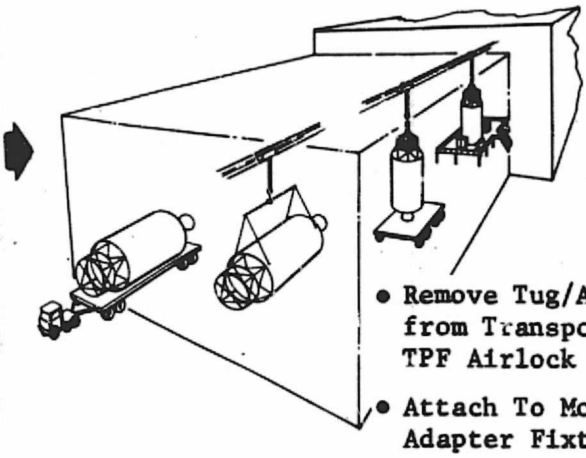


• Position Cargo Canister Transporter At Outside Door of Airlock
• Hydraulically Elevate Cargo Canister To Vertical Position
• Position Canister To Seal with Airlock Transfer Door
• Remove Canister Cover from Inside Airlock
• Install Payload In Cargo Canister
• Transfer To Pad

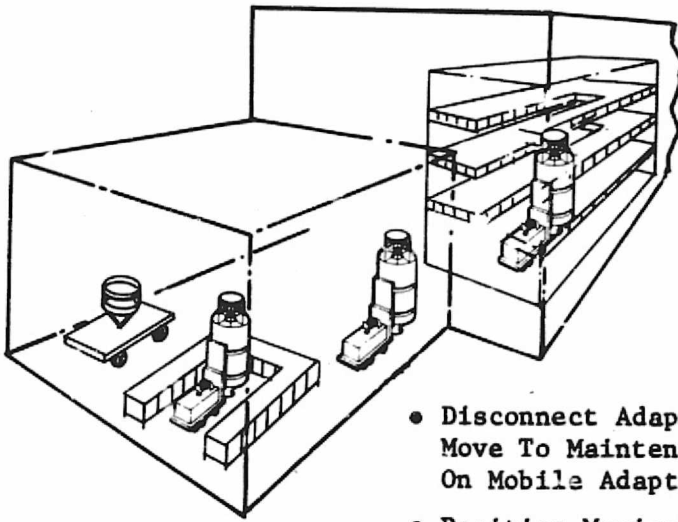


• Prepare PCR To
Payload
• Position Cargo
Transporter To
fer Rails
• Draw Canister
Payload Transp
• Remove Payload
with PCR Manip

Fig

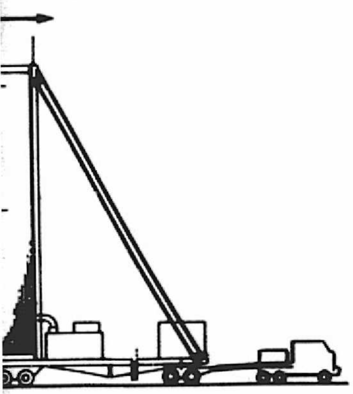


- Remove Tug/Adapter from Transporter In TPF Airlock Area
- Attach To Mobile Tug Adapter Fixture
- Pivot To Vertical Position
- Move To Airlock Precheckout Stand



- Disconnect Adapter and Move To Maintenance Area On Mobile Adapter Fixture
- Position Manipulator To Receive Tug At Precheckout Stand
- Transport Tug with Manipulator To Checkout Area Cell
- Install Tug In Checkout Cell

Outside Area



anister Transporter
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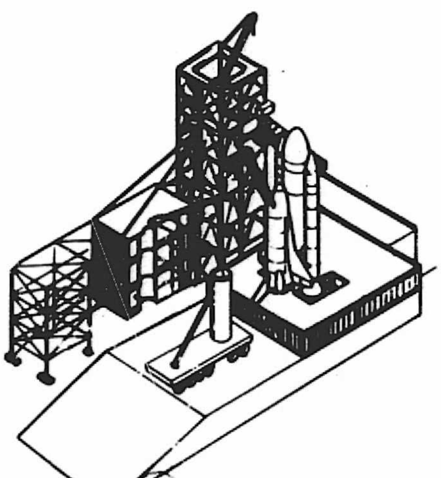
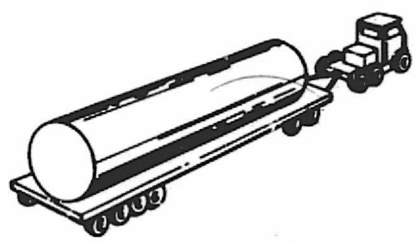
: To Seal with Airlock

Cover from Inside

In Cargo Canister



- Prepare PCR To Receive Payload
- Position Cargo Canister Transporter To PCR Transfer Rails
- Draw Canister Up Rails To Payload Transporter Position
- Remove Payload from Canister with PCR Manipulator



- Lower Empty Cargo Canister To Horizontal Position On Transporter
- Tow Cargo Canister On Transporter To Storage/Next Point of Use

Figure III-A-8 Normal Ground Movement at KSC

When the Tug transporter arrives at the TPF, any necessary washdown of the transporter or Tug cover will be completed outside the airlock area. The transporter will then be positioned in the airlock area. The Tug cover will be removed and a hoisting sling installed. The Tug will be disconnected from the transporter and lifted by the airlock crane. The prime mover will then tow the transporter out of the airlock area. A mobile Tug adapter fixture that can function as a pivoting adapter will be aligned in its horizontal position with the Tug adapter. While the Tug is supported by the crane and positioned with hydroset control, circumferential attachment will be made between the Tug adapter and the adapter fixture. A forward Tug lifting adapter will be installed and forward sling attachment completed. Handoff from the horizontal spreader sling to the forward sling will be completed and the airlock crane will lift the front of the Tug while the adapter end pivots and translates on the adapter fixture until Tug and adapter are vertically oriented. The Tug and adapter will be moved by crane and the mobile adapter fixture to position in an airlock precheckout stand.

When precheckout operations, including cleaning, have been completed, the aft adapter on the mobile adapter fixture will be disconnected from the Tug, removed from the stand, and positioned in the airlock area for inspection and cleaning. It will then be moved into the checkout area for maintenance operations. A payload manipulator will be positioned to receive the Tug at the precheckout stand. The manipulator arms will be attached to the Tug and the Tug will be removed from the stand and transported in vertical position from the airlock area to the checkout area cell. Cell installation will be completed and inspection and maintenance operations will commence. A self-powered manipulator is needed later in the process cycle to effect a sealed transfer of the payload into the cargo canister for transfer to the PCR. Its added use at this point in the flow to move the Tug from the airlock to the checkout area avoids either a handoff operation from the airlock crane to the checkout crane or the cost of extending the checkout area crane into the airlock.

When Tug maintenance and checkout operations are complete, a refurbished adapter on its mobile adapter fixture will be positioned at the aft end of the Tug in the checkout cell. The adapter will be installed on the Tug. Mechanical and electrical interface between Tug and adapter will be verified and additional system checkout operations performed.

A processed kick stage will be delivered to the airlock area of the TPF on its transporter. It will be transferred by the payload manipulator to the checkout cell where it will be lifted by crane and mated to the Tug. A processed spacecraft will be transported to the airlock area, transferred by the manipulator, and installed by the crane on the kick stage. The manipulator is proposed for

these moves, as it was for the Tug, to preclude crane handoff or major modification to move from the airlock to the checkout area. The manipulator arms would have to be designed to accept the smaller diameter kick stage and spacecraft as well as Tug. After functional interface tests and further system verification has been performed, the integrated payload will be prepared for movement. The payload manipulator will grab the payload, remove it from the checkout cell, and transfer it to the airlock. The payload will be positioned in the precheckout stand for APS loading. Support of the payload during the loading operation remains with the manipulator, but access is provided by the stand. Estimated worst-case weight of the payload at this point in the processing cycle is 27,000 pounds (12,245 kg).

At this point in the handling flow, we propose use of the 747 aircraft cargo canister, in its ground configuration, i.e., aerodynamic fairings removed, for ground transport of the processed payload from the TPF to the pad. It appears technically feasible and cost effective to assume multiple use of the canister and its transporter, which would provide the capability to raise and lock the canister in vertical position on the transporter for movement to the pad.

After APS loading and leak check, a clean cargo canister on its transporter will be positioned outside the TPF at the airlock door. The canister will be elevated to vertical position on the transporter by hydraulic ram and aft sliding translator. Once the canister is locked in loading position, it will be moved to the interface position with the seal on the transfer door. The cover of the canister will be removed from inside the airlock by the airlock crane. The manipulator will move the payload to the canister and position it in the canister where it will be secured at lateral tiedown points and at the adapter interface. The manipulator arms will be detached from the Tug and the manipulator will withdraw from the canister. Using the airlock crane and necessary access stands, the canister cover will be reinstalled. The transporter will be prepared for movement, security of the canister in vertical position will be established, and the payload in the canister will be towed to the launch pad.

The PCR, in retracted position, will be prepared to receive the payload. The cargo canister transporter will be positioned on the access ramp adjacent to the PCR with the canister oriented to vertical transfer rails on the face of the PCR. The canister will be attached to the rails and disconnected from the transporter. The PCR roof crane will be used to draw the canister up the rails to its interfacing seal with the PCR transfer door. PCR fold-down platforms will be positioned to provide personnel access to the canister cover. The internal PCR crane will be used to remove and retain the cover. Platforms will be folded as required to provide manipulator access to the payload and other preparations will be

completed for receipt of the payload. Operating from PCR base level, the PCR manipulator will move forward to the exposed payload in the canister. The manipulator arms will be attached to the Tug, the payload will be disconnected from its adapter and lateral tiedown points, and the manipulator will draw the payload out of the canister and position it in the PCR cell. The manipulator will track in this operation in the same mode that will be used to install the payload in the Orbiter after the PCR has been extended to interface with the Orbiter. The canister cover will be reinstalled from inside the PCR cell. The canister transporter will move the canister from its seal position, it will be hydraulically lowered to horizontal position, and towed to storage or the next point of use.

3.3.5 Transportation Support Activities - Transportation support activities will include development of overall transportation plans for primary or secondary modes of transportation. Separate delivery plans will be required for each of the material movements identified. Logistics management will also be responsible for planning and implementing adequate preservation, packaging, packing and marking techniques to assure in transit and handling protection for Tug and ship loose components. Logistics will schedule Tug transportation and will be responsible for availability of the transportation resources including necessary shipping containers, material handling devices, transportation documentation, and trained and certified transportation personnel. Logistics will also administer the use of commercial or government bills of lading as required by NASA.

3.4 Operational Data Requirements

The primary objective in selection or establishment of operational flight instrumentation (OFI) requirements was to maximize the use of condition-monitoring maintenance techniques. Consideration was given to using assessment techniques that would provide maximum health and trend data without addition of excessive data transducers.

The present baseline Tug configuration provides inherent capabilities to accomplish these objectives. Examples of these inherent capabilities are the defined data management and measurements subsystems. The central processor of the data management subsystem provides an almost limitless self-test and data storage capability which, with proper programming and memory sizing, can provide continuous hardware test, monitoring, and trend predictions as functions of normal operational commands. This condition should be exploited to the maximum extent possible.

The OFI requirements matrix (Table III-A-4) displays present measurement types and numbers that are estimated to fulfill the aforementioned objectives. It should be noted that of the 1322 measurements indicated on the matrix, 1037 represent evaluation of normal operational commands or self-test data. These measurements are identified as onboard checkout and current signature measurement, and the remaining 285 measurements are provided by various transducers or instruments located throughout the Tug.

3.4.1 Structures - The structures system OFI is primarily dedicated to measurement of dynamic and thermal loading of various structural elements of the Tug, as well as a variety of leak measurement devices. These OFI requirements are satisfied by addition of transducer and specialized instruments; 39 measurements are required.

3.4.2 Propulsion - The propulsion system requires 208 data measurements; 106 remote transducers and 102 evaluations of normal self-test and operational flight commands.

3.4.3 Thermal Control - The thermal control system requires 101 data measurements; 88 remote transducers and 13 evaluations of normal self-test and operational flight commands. However, most of the remote transducers are dedicated to evaluation of system performance.

3.4.4 Avionics - The avionics system requires 974 data measurements; 52 remote transducers and 922 evaluations of normal self-test and operational flight commands. The basis for this number of measurements is an estimate of 16 measurements for each avionics black box.

3.4.5 Development Flight Instrumentation - It is estimated that the defined instrumentation could conceivably increase by a factor of 1.5 because of the required acquisition of dynamic, static, and thermal loading assessment needed to complete design evaluations during early Tug flights.

3.5 Manpower Staffing

The overall Tug launch site crew size and makeup can be determined through an analysis of the stick-and-ball chart. The organization shown (Fig. III-A-9) would be typical for the refurbishment/checkout of a single Tug at KSC on a 2-shift per day basis. The crew size required to support the total fleet, including launches from ETR and WTR, will be provided in the fleet utilization subplan B.

Table III-A-4 OFI Requirements Matrix

System-Subsystem \ OFI Sensor Type	Temperature	Pressure	Vibration	Shock	On-board Checkout	Flow	Position	Voltage	Liquid Level	Depletion L-L	Hydrogen Leak	Oxygen Leak	Residual Gas Analysis	Contamination	Speed RPM	Current Signature	Totals
Structures	8	4	9	8							2	2	2	4			39
Forward Skirt			3	3													6
Main Skirt			3	3							2	2	2				12
Liquid Hydrogen Tank	4	2												2			8
Liquid Oxygen Tank	4	2												2			8
Aft Adapter			3	2													5
Propulsion	8	35	2		26	6	32	7	8	4					4	76	208
Main Engine	3	6	2				3								2		16
Feed-Fill-Drain-Vent LH	1				1		7	2								8	19
Feed-Fill-Drain-Vent LO	1				1		5	2								6	15
Pressurization		6					8									13	27
Hydraulic						2	4	1	2						2	1	12
Propellant Load-Measure								2	6	4							12
APS	3	23			24	4	5									48	107
Thermal Control	66	8			5	5	6		2						1	8	101
Active T/C	12	2			5	3	3		2						1	3	31
Passive T/C	30																30
Insulation-Purge	24	6				2	3									5	40
Avionics	8				922		10	24	4	2	1	1		2			974
Nav.-Guid.-Control					240												240
Data Management					256												256
Communications					69												69
Measurements					229												229
Electrical Power Distr.	8				128		10	24	4	2	1	1		2			180
Totals	90	47	11	8	953	11	48	31	14	6	3	3	2	6	5	84	1322

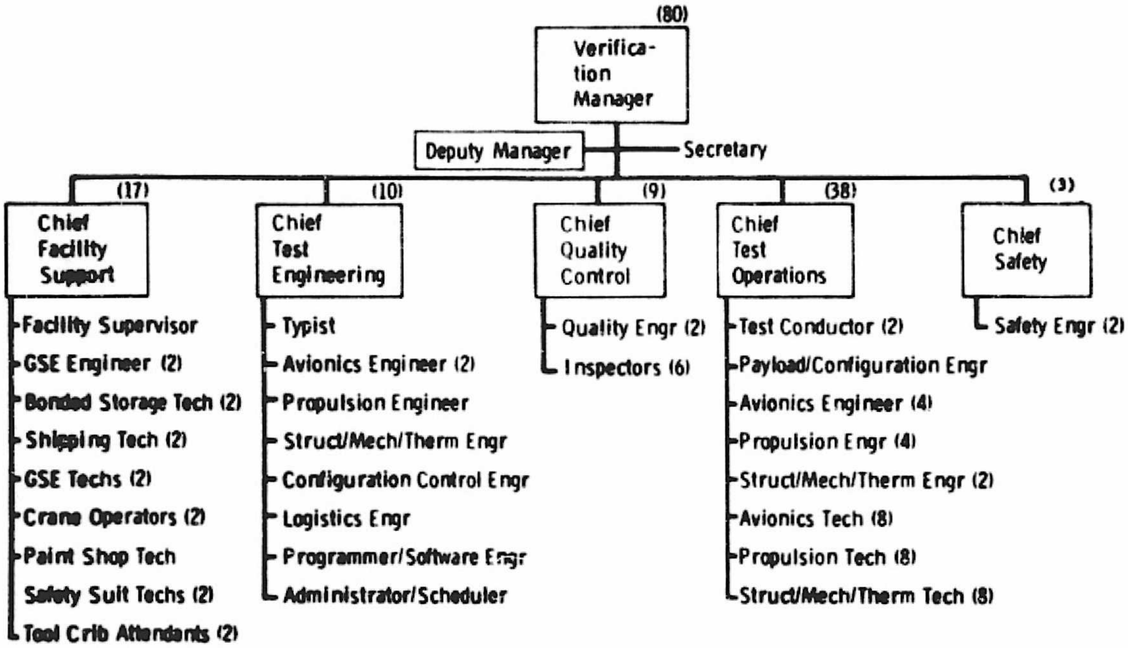


Figure III-A-9 ETR Launch Site Operations Crew Size

In staffing this organization of 80 people, consideration was given to peak work loads and slack time. During periods of slack time operations personnel would be involved in off-line refurbishment, checkout, and calibration of flight components and GSE units. During periods of peak Tug activities, facility support personnel will supplement test operations personnel.

Doubling the number of Tugs through the refurbishment/checkout/launch cycle would not double the crew size because all operations would be phased to better use the GSE, facility, and available manpower. Within the organization, fluctuations on number of Tugs processed will have minimum impact on the test operations group.

3.6 Safety Requirements and Support Plan

This section of the subplan provides safety data on normal Tug ground operations flow identified in Figure III-A-2. The following paragraphs contain general information on safety policy and philosophy, definition of hazardous operations, and identification of safety requirements. Safing requirements associated with abort modes will be defined in fleet utilization subplan B where contingencies are addressed.

The basic safety policy of the Space Shuttle Program is to impose the minimum safety requirements on the Space Transportation System (STS) and its users to protect the flight and ground personnel, the

STS elements and payloads, the general public, public/private property, and the ecology. Normal Tug ground operations include inherently hazardous operations that must be controlled and reduced to the lowest practical level consistent with program objectives, cost, and schedule.

During flight operations, the Tug contains energy sources that constitute potential hazards but are required for mission accomplishment. These hazards have been reduced to an acceptable level for flight operations by design features (safety factors, etc) and by providing for the control of the energy sources. The Tug safing philosophy, however, must be to eliminate each energy source as soon as practical after the mission requirements for that energy is completed. Postmission Tug safing, therefore, is actually accomplished incrementally during recovery, reentry, and postlanding operations as shown by Figure III-A-10. Postlanding safing considerations include operations with the Tug in the Orbiter payload bay and after removal. For normal turnaround operations, it is considered neither essential nor practical to achieve an absolute safe (completely inert) Tug status, but hazard levels will be reduced to an acceptable level before performance of required activities.

Incremental Tug Safing to Eliminate/Reduce Energy Sources as Mission Permits

Monitor and Control Any Residual Hazards

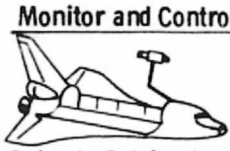
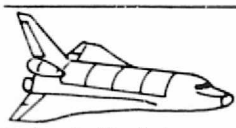
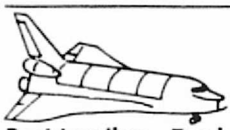
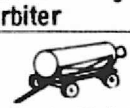
 Prior to Retrieval	Main Propellants Vented
 Prior to Re-Entry	APS Secured Tug/Orbiter Interfaces Verified Tug Electrical Power Sources Put On Standby Tug Electrical Power Supplied by Orbiter Fuel Cell Reactants Vented
 Post Landing - Tug in Orbiter	Orbiter Crew Requirements (OLF) Ground Control (OLF) Control Tank Pressure, Integrity Verification, Purge Hazardous Vapor Detection Ground Crew (OPF) H_2 Vent to Burn Stack
 Prior to Maintenance	Remove Hydrazine Residuals (TPF) Remove Auxiliary Battery (TPF) Verify Integrity Pressure System (TPF) Decay Leak, Vent to ≥ 4 Safety Factor H_2 Vent to Burn Stack, Lock Up Blanket Pressure Monitor Pressure Via LPS

Figure III-A-10 Tug Postlanding Safing Philosophy

Extending the safing philosophy through turnaround and launch preparation activities dictates that energy sources be added to the Tug as late in the flow as practical. Positive control of the energy sources must be maintained by GSE directly or through the Orbiter interfaces as applicable. Procedural constraints will then assure safe normal ground operations.

3.6.1 Hazards Present at Landing - Hazards associated with normal Tug ground operations include residual hazards present at landing and those inherent to or induced by the operations.

Based on assumed prelanding safing actions, the following Tug potential hazards may be assumed to be present upon Orbiter landing.

Chemical energy in the form of residual hydrogen vapor and hydrazine will be present. The liquid hydrogen residuals will have been expelled from the main propellant and fuel cell reactant tanks in orbit. Previous studies have shown that the tanks can only be cycled to 1 psi (6.89×10^3 N/m^2) on orbit rather than to vacuum, because of the risk of hydrogen freezing below 1 psi (6.89×10^3 N/m^2). Consequently, some residual vapor will remain. The APS will be secured by closing the series redundant thruster valves with residual hydrazine in the tank and lines.

Pressure energy will be present in the main propellant tanks, fuel cell reactant tanks, and the pressurization systems. Before entry, the main propellant tanks will be pressurized to a level to preclude implosion during landing. The pressurization systems will contain residual pressurants. These pressures will vary as a function of temperature changes during and after landing.

The partially discharged auxiliary (flight) battery presents an electrical energy source.

No ordnance devices have been identified in the baseline configuration, so safing requirements for ordnance systems have not been included at this time.

3.6.2 Operations Hazards - The normal ground operations flow shown in Figure III-A-2 and detailed on the Function Description Data Sheets contained in Appendix A, includes the following inherently hazardous operations:

3.6.2.1 Tug Handling - The Tug is moved, hoisted, and/or rotated several times during ground operations. Each instance is considered a hazardous operation, primarily because of the accident/incident frequency rate during any handling operation.

3.6.2.2 Propellant Transfer - The Tug propellants include LO_2 and LH_2 main propellants and N_2H_4 for APS. The main propellants are loaded during Shuttle launch countdown and residuals are dumped

before retrieval. The APS is loaded in the TPF before Shuttle mate and will normally require draining residuals and purging after removal from the Orbiter.

3.6.2.3 *Cryogenics Transfer* - The Tug fuel cell reactants, LO_2 and LH_2, are loaded after the Tug is mated with the Orbiter. It is assumed that residual reactants are expelled before Orbiter landing.

3.6.2.4 *Pressurization* - The Tug pressurization system is partially loaded before movement to the pad and completed after Tug/Orbiter mate. The pressurization system, main propellant tanks, and fuel cell reactant tanks are maintained at partial pressure throughout the turnaround cycle.

3.6.2.5 *Electrical Power* - The flight battery is installed before movement from the TPF. Power is supplied to the Tug by the GSE electrical power supply (A-001) during test and/or repair operations.

3.6.3 Safety Requirements - The operational requirements for safe turnaround operations include postlanding safing and those necessary for hazardous operation. The postlanding safing requirements during operations with the Tug in the Orbiter payload bay is discussed in the following three functional areas.

3.6.3.1 *Tug in Orbiter Payload Bay* - Because the Orbiter flight crew has prime responsibility to monitor and control safety critical Tug functions, they will make a final check to ensure all Caution and Warning (C&W) parameters are within limits before egress. The flight crew will also initiate and verify transfer of control Tug functions to Ground Control.

The Tug Ground Control will monitor the C&W parameters with particular attention to tank pressure levels during postlanding temperature variations. In the course of monitoring tank pressures and temperatures, Ground Control will verify the pressure integrity of all tanks in the gross terms available with flight instrumentation. These first two sets of requirements will be accomplished at the OLF.

The Orbiter ground operations crew will establish the payload bay purge to neutralize any hazardous vapors. The exhaust from the payload bay purge will be subjected to hazardous vapor detectors to ensure freedom from leaks. In the event the hydrogen tanks require venting, the Tug H_2 vent will be connected to the burn stack via the Orbiter. These operations are performed in the OPF.

3.6.3.2 *Tug Removed from Orbiter Payload Bay* - The Tug safing for turnaround operations is completed after removal from the Orbiter payload bay and transport to the TPF airlock. The following four

requirements are established to reduce the hazards to an acceptable level for turnaround activities.

1) The APS tanks and lines will be drained of residual liquid hydrazine. The system will then be purged and sealed with a dry nitrogen blanket.

2) The auxiliary (flight) battery will be disconnected and removed from the Tug.

3) All Tug pressurized systems will be leak checked with helium at maximum operating pressure to verify the systems integrity. Upon completion of the leak check, each system will be vented to a pressure of one-fourth or less of the design burst pressure and sealed. Hydrogen systems will be vented to a pressure of one-fourth or less of the design burst pressure and sealed. Hydrogen systems will be vented to a burn stack for disposal of any residual hydrogen vapor when reducing to the one-fourth design burst level. The remainder of processing will be accomplished with the tanks locked up to this blanket pressure.

4) Pressure systems will be monitored by the LPS during turnaround activities to ensure that pressure levels remain in limits. Continuous monitoring is not required because pressure changes are a function of temperature change and the Tug is in a controlled environment during turnaround. A temperature change of 30°F (17°C) would produce a pressure change in the order of 1.0 psia (6.89×10^3 N/m^2) on the largest (hydrogen) tank.

The safety requirements imposed by hazardous ground operations include those applicable to Tug, GSE, and facility design, and definitive operations procedure detail. The GSE and facility safety design requirements have been included in the Tug GSE Requirements Specification Data Sheets, contained in Appendix B, or the Tug Facility Requirement Specification Data Sheets, contained in Appendix C. The operations identified as hazardous on the Function Description Data Sheets are common to current aerospace projects and specific operational constraints are well known and accepted. These constraints are considered applicable to specific functions or steps to operating procedures that will be developed during future Tug program phases.

The applicable safety requirements contained in para 3.2.6 of the Baseline Space Tug Requirements and Guidelines (MSFC 68M00039-1) have been included in the appropriate functional data sheets or specification data sheets.

3.6.3.3 Safety Requirements Exceptions/Recommended - Paragraph 3.2.6.1.3.b(1) states "Tug lift/hoist mechanism shall be designed to be fail operational/fail safe". It is recommended that control

systems shall be designed to be fail operational/fail safe. Mechanical components shall be fail safe or provide a factor of safety of 5.0 times static load.

Paragraph 3.2.6.1.3.b(2) states "Transportation and hoisting load limits, static and dynamic, shall be (TBD) less than flight load limits in all cases". It is recommended that the (TBD) be deleted.

3.7 Fleet Utilization and IUS/Tug-to-Payload Integration Requirements

(Not applicable)

3.8 Site Activation and Verification

(Not applicable)

3.9 Checkout Ground Software Development

Software Requirements Data Sheets have been prepared for each operational phase functional step and these are included in Appendix D. The following discussion relates to software considerations in the operational phase. A general discussion is the basis for illustrating operational impacts.

Software for all major systems fall into four classifications: Operating system, application programs, language processors, and support programs. The operating system provides general linkage routines that are not specifically related to the testing process, i.e., linkage to input/output routines for all peripherals, linkage to CRT display routines, data base control and modification, loading and control transfer to operating programs, and linkage to support subprograms. Application programs include both the test procedure sequences written in GOAL language and the source programs necessary to process those instructions once they have been converted into machine language. Language processors convert GOAL language into machine executable form and support the execution of the converted programs. Main parts of the language processors are compilers and the run-time (loader-executor) support package. The support programs include libraries of routines, simulators, software validation routines, data reduction and analysis programs, training aids, and utility programs that support programming preparation and debugging.

3.9.1 Nonrecurring Software - During the operational phase, software will be either nonrecurring or recurring relative to its generation, as illustrated by Table III-A-5.

Table III-A-5 Software Requirements

Functional Division	Number of Functions Requiring Software: Nonrecurring	Recurring	Totals
1.0 Postflight safing	3	0	3
2.0 Scheduled maintenance and refurbish	9	1	10
3.0 Unscheduled maintenance and refurbish	0	0	0
4.0 Postmaintenance checkout	14	10	24
5.0 Tug/payload mating and checkout	7	2	9
6.0 Tug/shuttle mating and checkout	1	2	3
7.0 Prelaunch checkout	2	1	3
Totals	36	16	52

The nonrecurring software (operating systems language processors, and most support programs) will have been developed during the activation phase; this software is not expected to change because of the fixed systems it services. The nonrecurring software will generally remain fixed and the recurring software will be integrated with it and worked around it.

3.9.2 Recurring Software - The recurring software (application programs and some support programs) results from changing components, systems, methods, payloads, and requirements. One-third of the Software Requirements Data Sheets estimate that these functions will require continuing software attention. As expected, LRU element changes and its software waterfall up through subsystem test, element test, combined system test, and integrated test and countdown. The orderly expansion and modification of software at each test sequence is achieved by proper core sizing and using standard data base modification methods.

3.9.3 Software Optimization - Optimization of a subsystem or system affects the software in the same manner as LRU changes discussed previously. Optimization implies simplification; however, system simplification does not necessarily imply software simplification. It is very possible that simplification may trade hardware for software or institute firmware in the form of microcoded elements or PROMS. As before, software modifications would program changes through every test level impacted by the optimization.

Support programs will assist in the software preparation and provide debugging support and simulators and software validation routines for verification and limited validation. These support programs are expected to be relatively fixed requiring no continuing software modifications.

In the operational phase, no major changes to the software are expected unless there is a technological breakthrough that materially affects programming in general. Other minor or continuing changes have been identified and discussed.

3.10 Operational Logistics/Maintenance

Tug operational logistics must provide the integrated support necessary to assure that qualified personnel with adequate equipment and data resources can maintain operational turnaround in an efficient, timely, and cost effective manner. Maintenance and repair, maintenance equipment, spares and supply support, training, operational maintenance documentation, transportation and handling, support facilities, and sustaining support functions must be provided for the operational phase. Implementation of the Tug ground operations functional flow diagram presented in Figure III-A-2 will depend heavily on successful maintenance and repair activities. Much of the details of logistics implementation will depend on further program definition. Basic assumptions were made for the purpose of this study based on a review of Shuttle program documentation and specific application of the requirements established by Volume XII, Integrated Logistics, JSC 07700 and the KSC Shuttle System Ground Operations Plan, K-SM-09.

1) Level I maintenance activity will be predominantly remove and replace at the LRU level and will be performed off-pad at the TPF.

2) Supporting Level II maintenance for failure verification, minor repair, and disposition of Level I items will be performed at the KSC repair shops.

3) Level III fault isolation and repair beyond Level II capability will be performed at the Tug contractor's or supplier's facility during the manufacturing cycle and at a NASA Depot thereafter.

4) Minimum scheduled maintenance will be performed to reduce Tug downtime and to support turnaround time requirements.

5) A computerized program should be considered for maintenance of logistics software and statusing of the supply support program.

6) Maximum deferred spares procurement will be obtained through use of production assets.

7) The majority of maintenance and checkout functions for both KSC and WTR will be performed at the TPF, which will function as a common Tug maintenance and checkout facility at KSC.

8) Maximum use will be made of the Tug contractor's and supplier's equipment, technical documentation, production spares, and training to support operational implementation.

9) The Tug contractor will supply limited sustaining logistics engineering to KSC for the initial phase of the operational program.

3.10.1 Logistics Management - Logistics management, discussed more completely in Subplan B, will be responsible for the planning, scheduling, statusing, and control of Tug logistics implementation. Personnel aspects will include trained and certified engineers and technicians for initial and sustaining operations. Hardware responsibilities will encompass spares, repair parts, consumables, modification kits, maintenance equipment, and facilities. Documentation will include operation and maintenance manuals, modification instructions, transportation and movement plans, training support data, and field support plans.

The Logistics Support Analysis, initiated during the design and development phase, should be updated during the operational phase to reflect experience gained. Support analysis will be concerned with optimization of the requirements established by maintenance, training, and transportation analyses. Levels and location of maintenance, repairable and nonrepairable status, repair locations, and supply categories resulting from the maintenance analysis should be validated, modified, and expanded based on operational requirements. Training curriculum and techniques should be modified to satisfy the operational environment. Transportation plans should be changed to improve schedules, reduced shipping costs, and improve the security of cargo in transit. Updated support analysis should control and reduce Tug operational program costs by maintaining a current "best logistics" approach to support requirements.

3.10.2 Maintenance and Repair Activity - The basic operational concept for Tug will be to remove and replace to the functional line replaceable unit (LRU) unless repair in-place is justified by cost and minimal impact to turnaround time. Scheduled replacement will be based on predictable wearout and unscheduled replacement will be predicted on degradation or malfunction indicated by OFI and ground system checkout. Use of condition monitoring techniques for maintenance prediction will take on a new dimension for the entire Shuttle program including the Tug.

Maintenance and checkout personnel will be involved in review of the flight instrumentation data as a prerequisite to development of the Tug postflight maintenance activity plan. Development of

the plan will target maintenance and repair activities and reduce the scope of scheduled maintenance. Maintenance performed on Tug and associated support equipment will be categorized as Level I organizational, Level II intermediate, or Level III depot. Preventive maintenance will be performed to retain components in specified condition and corrective maintenance will restore Tug items to a specified condition after malfunction. Level I maintenance, performed at the TPF, will include all maintenance activities accomplished directly on installed hardware such as fault isolation, removal and replacement of components and subassemblies, servicing, replenishment, inspection and limited repair in place. The TPF will house necessary GSE, tools, equipment, technical documentation, and trained personnel to support the Level I activities. Level II maintenance, performed at KSC repair shops, will involve disposition or repair of hardware removed during first level activity and will provide for the removal, replacement, repair, calibration, adjustment, checkout, test and inspection of the lowest replaceable part consistent with capabilities at the repair shops. Depot, or Level III, maintenance will disposition or repair hardware removed during first or second level maintenance. It will be performed at the Tug contractor or supplier's facility during the production cycle and at the NASA depot thereafter.

Level I and II postflight maintenance activity for both KSC or WTR launches will be performed primarily at KSC. Limited servicing, visual inspections, and health tests will be performed at WTR but principal maintenance functions will be performed at KSC.

Modifications resulting from design change will be incorporated at the TPF. Modification kits for support equipment and spares will be assembled and shipped by the Tug contractor. They will be controlled, inventoried, and issued at the TPF for installation by TPF personnel in accordance with instructions addressed in the engineering change proposal. Unique installations will be supported by contractor or supplier personnel as required.

3.10.3 Maintenance Equipment - Maintenance equipment, including electronic and mechanical test equipment, lubrication and servicing equipment, common and special tooling, will be available at the TPF. This equipment will be statused and controlled as part of the property management program for that facility. Equipment in this category will be maintained to the greatest extent possible at the TPF by Tug maintenance and checkout personnel and repair or servicing beyond that facility's capability will be accomplished at the KSC repair shops, the supplier's facility, or the depot.

3.10.4 Spares and Supply Support - Spares required to support the operational Tug program have been initially identified on the Maintenance Requirements Data Sheets included in Appendix E of this report. These initial assessments will have undergone several refinements through the contractor's maintenance analysis process

before spares acquisition is initiated. Identified spares will be drawn from production quantities to the greatest extent possible to implement the concept of delayed procurement. Production components used to support spares requirements will be replenished from the spares inventory. The advantages of this approach lie in reduced risk of purchasing spares that may become obsolete based on advanced state-of-the-art systems for Tug, reduction in total spares cost, and spread of spares cost over a larger portion of the Tug program. During the early operational phase, selected production components will be maintained at the TPF for Level I maintenance action. Components not considered critical to the maintenance flow will be retained at the Tug contractor's facility and shipped on an "as required" basis. As the spares acquisition process matures, production items used as spares will be replenished from the spares inventory. When the production cycle nears completion and spares requirements are better defined based on usage, major spares acquisition to support remaining program requirements may be completed. Level III spares will be maintained at the contractor's or supplier's facility until a NASA depot is in existence, at which time they will be shipped to the depot.

The Tug contractor will manage contractor-supplied spares and NASA will manage those spares that it provisions. This implies contractor logistics support on site during the early operational phase when production spares are being maintained on site. (See subplan B for additional details.)

3.10.5 Training - Training will be required for Tug maintenance and checkout personnel, many of whom will be required to be certified in their job specialties. Initial Tug familiarization and orientation will have been obtained through attendance at contractor training courses at the contractor's facility, MSFC or KSC. Video tape will be used where practical. Normal attrition, design change, and the requirements for recertification in skill training areas will require on-going training during the operational period. The Tug contractor will supply this training, live and video, on site at KSC during the preoperational and early operational phases. Training scope and level of detail should be aligned with Levels I and II maintenance and checkout requirements as established by the contractor's support requirements analysis. Maximum use will be made of O&M manuals to support the training function and tie it to the maintenance activity. Tug contractor sustaining engineering personnel at KSC will implement job experience training to supplement classroom and video presentations. Safety training and facilities interface training will be the responsibility of KSC. (See subplan B for additional details.)

3.10.6 Operations Maintenance Documentation (OMD) - OMD for use at the TPF and on-pad for servicing operations will be based on Tug contractor prepared O&M Manuals. These manuals will be transmitted to MSFC for development of the preliminary configuration

manuals that MSFC will deliver to KSC. Remote terminals or microfiche viewers and printers will be used to access the central file of O&M data at the Tug contractor's facility. KSC should also access in this manner for either O&M data or the contractor's engineering, manufacturing process, test, and transportation data. Trained and experienced technicians, familiar with Tug equipment, will operate with system and component OMIs and procedures prepared by KSC to perform scheduled maintenance, isolate malfunctions, remove and replace at the LRU level, service, or disposition items to Levels II or III activity. The basic O&Ms prepared by the contractor will contain detailed information for both on-line and off-line functions and will detail scheduled and corrective maintenance tasks. Handling and storage information as well as pertinent GSE data will be supplied in the basic O&Ms. Supplier documentation should be made available to NASA by the Tug contractor. (See subplan B for additional details.)

3.10.7 Transportation, Handling, and Packaging - Tug transportation and handling requirements, more fully discussed in Section 3.3 includes transportation between KSC and WTR, delivery from the manufacturer to KSC, and ground movement at KSC. Air transport using a cargo canister piggyback configuration on the 747 will be the primary mode of transportation. Over the road transportation support equipment will be required for transporter movement from the manufacturer to the 747 airfield and at KSC and WTR. A Mate/Demate Fixture (MDF) will be used to lift and position the Tug in a cargo canister on the 747. Flight support hardware will be used for tiedown, bracing, and inflight functional monitoring and control. KSC receipt, ground movement, and shipment to WTR will require similar equipment to that used in the manufacturer's transportation cycle. Transporter concepts must be evaluated for payload movements of the combined Tug, adapter, and spacecraft. Transportation plans must be developed for the major movements described above. Individual delivery plans must be developed for each specific transportation configuration. Preservation, packaging, and marking requirements will be developed as part of the transportation analysis to assure that there is no degradation of reliability or function of Tug components during the transportation, storage, and handling phases.

Handling personnel must be trained in all aspects of the transportation and movement process and should be certified in their respective transportation crew assignments.

3.10.8 Logistics Support Facilities - The Support Requirements Analysis will fully define facility needs for the logistic support activity during the operational phase. Typical requirements will include adequate floor space and installed equipment at the TPF to accomplish Level I maintenance functions, a minimal but dedicated training area at the TPF, or in existing NASA facilities with video equipment, adequate storage, and processing area for

spares at or remote to the TPF, and a storage and issuance area for maintenance and training technical documentation. Reproduction services will be required either at the TPF or in close proximity NASA facilities.

3.10.9 Sustaining Support - During the initial phase of the operational Tug program, the Tug contractor's logistic engineering personnel at KSC should work in conjunction with maintenance engineering to assure identification and availability of production spares. They should review requirements, establish need dates, and determine spares availability and receipt for items stocked at the contractor's facility. They should manage the contractor's production spares inventory and perform spares issue, disposition of failed items, inventory control and consumption reporting, replacement items turnaround, and transportation arrangements. They should also arrange for and schedule contractor-supplied training and operational technical documentation and process modification kits through the engineering change control cycle.

3.11 Configuration Management

The recommended method for the implementation of Configuration Management disciplines to achieve effective control over the hardware, software, and operational activities of the Tug Ground Operations Project is reflected in para 4.4 of subplan B. Specific recommendations for the elimination of redundant control of the facility configuration after the completion of activation are discussed here.

3.11.1 Facility Configuration Control - Normally, control of facility configuration is maintained through baselined facility Architectural and Engineering (A&E) drawings that are maintained in an as-built condition reflecting authorized changes, and the Facility Criteria and Interface Document that is also maintained to show all approved changes affecting criteria or interface.

The facilities are defined during the definition phase by the Facility Criteria and Interface Document. At the time of baselining the facility, the A&E drawings are in consonance with these documents.

3.11.2 Architectural and Engineering (A&E) Maintenance - After baseline, all proposed changes to the facility are processed through the Facilities Change Request (FCR)/Facility Engineering Change Proposal (FECP) system. All PCRs/FECPs are coordinated, reviewed, and acted on by the Facility Working Group (FWG). Members of this group include all affected NASA/DOD agencies and contractors. One of the charter functions of the FWG is to identify interface effect of an FCR on any member of the FWG. The FWG directive, in addition to documenting FWG actions, provides for signatures of members indicating their agency's concurrence, nonconcurrence, or no effect.

All FWG concurred Class I facility changes are forwarded to the Configuration Control Board (CCB) for consideration.

The A&E drawing custodian has the responsibility of incorporating approved facility changes into the A&E as-built drawings. Therefore, upon completion of the approved facility change, the implementing agency forwards copies of their as-built engineering to the A&E drawing custodian through the FWG chairman.

3.11.3 Facility Criteria and Interface Document Maintenance - In addition to the A&E drawing maintenance, changes to existing interfaces and criteria, as well as additions of new criteria or interface requirements, are reflected in the Facility Criteria and Interface Document through the normal interface change loop. Updating of these interface documents requires a parallel coordination/approval loop to the FCR/FECP coordination/approval loop.

The custodian of the facility document prepares the change based on coordinated criteria and design requirements of affected agencies and contractors. The custodian submits the change to the CCB for disposition. A secondary distribution of information copies is made to the membership of the FWG. The custodian updates the document after approval by the CCB.

3.11.4 Changes to Airborne and Support Equipment - Configuration Control of airborne and support equipment affected by changes to the facility is achieved through change system described in para 4.4 of subplan B.

3.11.5 Suspension of Facility Criteria and Interface Document Maintenance - Maintenance of the Facility Criteria and Interface Document should be suspended after the facility becomes operational and the baselined A&E drawings become the authorized configuration and, therefore, the specification for the facility. These drawings are updated to the latest configuration through the FCR/FECP loop. Maintenance of the facility document would be meaningful if facility construction was on a production-type basis.

The same agencies and contractors involved in the interface change coordination and approval loop are also members of the FWG. All facility changes are originated as FCRs and coordinated through the FWG. Therefore, the FCR is an adequate medium for coordinating facility interface problems.

Concern of losing visibility of interface effect may be anticipated in the area of written criteria or "parametric interfaces"; however, this information is shown in the A&E drawings. Successful operation of the proposed system of maintaining only the A&E drawings after baselining of the facility will come about if drawings are maintained diligently.

3.12 *Timeline Funding*

Operations phase funding from January 1984 through December 1991 is shown in Table III-A-6. These costs are based on fiscal year 1974 dollars. (See Vol III for detailed cost breakdown.)

Fleet Utilization Project Management costs include project level cost/performance management, depot maintenance, long range scheduling of the Tug fleet, and sustaining engineering.

Ground and launch operations at WTR include the cost of the launch/recovery support crews, propellants, spares, and facility maintenance.

Ground and launch operations at WTR include the cost of the operational crews supporting refurbishment at the central processing facilities, checkout crews, facility maintenance costs, propellants, spares and central warehousing.

Table III-A-6 Timeline Funding (Millions $)

Project Function	Calendar Year								Total
	1984	1985	1986	1987	1988	1989	1990	1991	
Fleet Utilization Project Management	7.22	7.46	7.64	6.97	6.97	6.76	7.86	7.39	58.26
Ground and Launch Operations, ETR	5.78	6.21	6.21	5.87	5.87	5.70	6.38	6.21	48.24
Ground and Launch Operations, WTR	0.84	0.60	0.84	0.60	0.60	0.60	0.84	0.60	5.52
Ground Operations Total	13.85	14.27	14.70	13.44	13.44	13.06	15.08	14.21	112.05
Average Cost/Flight for Ground Processing = $0.68 M per flight									

CONTENTS

Table

B. IUS AND TUG FLEET UTILIZATION SUBPLAN (TASK 3)

1.0 Introduction

Fleet utilization is concerned with fleet sizing, fleet management, resource requirements, and contingency definition/planning. The contract requires that a set of 12 standard study elements be addressed as applicable in each subplan. To maintain standard paragraph numbers, 3.1 - 3.12 of each subplan have identical headings. This document provides planning data for nine of the 12 standard study elements as they relate to fleet utilization. The other three are not applicable. The applicable study elements include:

1) ground operations flow (contingency planning);

2) facility and GSE requirements;

3) transportation requirements and support;

4) manpower staffing;

5) safety requirements and support;

6) fleet utilization and IUS/Tug-to-Payload integration;

7) checkout ground software approach;

8) logistics/maintenance; and

9) configuration management.

The study elements not applicable to fleet utilization are:

1) operational data;

2) site activation and verification; and

3) timeline funding.

2.0 General Requirements

2.1 Ground Rules

The ground rules applied to this subplan follow.

1) The expendable IUS and Tug traffic model is that defined in MDC G5452, IUS/Tug Payload Requirements Compatibility Study First Progress Review and Data Exchange, September 1974, McDonnell Douglas Astronautics Company, and is included in Table III-B-1.

Table III-B-1 Traffic Model - Number of Flights

Configuration \ Year	1980*	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total
Expendable IUS - No Transition	9	16	14	17									56
Expendable IUS - 1 yr Transition	9	16	14	17	7								63
Expendable IUS - Residual Flights through 1991	9	16	14	17	7	4	3	1	1	2	1	1	76
Reusable IUS - No Transition†	10	20	14	16									60
Reusable IUS - 1 yr Transition†	10	20	14	16	8								68
Reusable IUS - Residual Flights† through 1991	10	20	14	16	8	5	4	2	2	2	2	2	87
Tug - No Transition					19	22	24	18	18	16	26	22	165
Tug - With IUS Transition and Residuals					13	19	23	18	18	16	26	22	155

* 1980 Totals from Martin Marietta IUS Study Data (For SAMSO)
† Reusable IUS Totals from Martin Marietta IUS Study Data (For SAMSO) - 1984 through 1991 Data Derived

2) The expendable IUS to Tug transition traffic model is that defined in NASA-MSFC letter PF-02, dated 2 October 1974, Mr. Huffaker to Mr. Etheridge, subject: *Mission Model Capture Data* for Sensitivity Analysis on the Tug Fleet and Ground Operations Schedules and Controls Study, and is included in Table III-B-1.

3) The IUS, Tug, and kick stages (as required) will be a part of the STS and launched by the Shuttle system.

4) All IUS operations will be performed at ETR.

5) Tug operations will be performed at both ETR and WTR (as specified in the traffic model). All Tug processing will be accomplished at KSC (ETR). Tugs scheduled to be launched at WTR will be shipped to WTR from KSC in a near-launch-ready condition.

6) The Tug will become operational in late 1983. Dual operations (IUS and Tug) will exist during the phase-over period and possibly the subsequent operating years.

7) All DOD payloads will be treated as secure payloads.

8) DOD and NASA IUSs and Tugs will be essentially identical and considered interchangeable for various/mixed missions.

9) The DOD will develop and provide the IUS.

10) The NASA will develop and provide the Tug and kick stages.

2.2 *Guidelines*

The following guidelines have been used to support the data, conclusions, and recommendations of this subplan:

1) In the pre-Tug era, the DOD (or DOD contractor) will perform IUS checkout operations.

2) For non-DOD flights, the DOD will provide a mission ready IUS to the using agency.

3) NASA will perform Tug refurbishment and checkout operations.

4) For non-NASA flights, the NASA will provide a mission ready Tug to the using agency.

5) IUS or Tug processing is performed by the using agency after spacecraft to IUS (or Tug) mate.

6) Resource requirements are based on:

    a) 5-day work week;

    b) two 8-hour shifts per day (one 8-hour shift per day at WTR);

    c) launch bi-weekly - even launch centers (maximum), (2 launches per year at WTR).

7) Tug and IUS requirements based on:

    a) maximum of 20 flights per Tug or reusable IUS;

    b) one Tug or reusable IUS lost per 100 flights;

    c) nondedicated (NASA or DOD) Tugs or IUSs.

8) The IUS may be either expendable or reusable, and planning considers both.

9) The reusable IUS traffic model is based on SAMSO, SR-IUS-100, Systems Requirements Document, Appendix III, Change No. 1, 1 October 1974, as used by Martin Marietta in an IUS study for SAMSO and derived data. The traffic model is included in Table III-B-1.

3.0 Operational Phase Study Elements

3.1 Ground Operations Flow (Contingency Planning)

The ground operations flows documented in Subplan A are "green light" and make no provisions for contingency planning. Efficient Tug fleet utilization must consider the effect of contingencies and make provisions in the system for handling them if and when they occur.

The contingencies considered fall into three categories: system element "no-shows", system element "no-gos", and programmatic changes (priority payloads, schedule changes, etc), and each contingency has been analyzed and documented in Section 5.0 of this subplan to indicate alternative actions available if such contingency occurs at various times in the operational flow. Figures III-B-1 through III-B-3 summarizes these alternatives. Individually and collectively these contingencies suggest several provisions which should be provided initially in the system to minimize any impact the contingencies may have on the program.

3.1.1 Provide Real Time Flexible Spacecraft Alternatives _ Several contingencies that may preclude a given spacecraft from being launched on schedule can occur. These include: a spacecraft no-go, spacecraft no-show, interface no-go, kick stage no-go/no-show or, a priority spacecraft. If the contingency does not involve a priority spacecraft, several choices present themselves:

1) Eliminate the contingency, schedule permitting.

2) Launch without the spacecraft. This may be applicable in multispacecraft missions or deploy/retrieve missions.

3) Launch with a degraded spacecraft. This would be a real time decision.

4) Provide buffer spacecraft in the program to fly as substitutes. This implies standby or buffer spacecraft.

5) Swap launches with one of next few spacecraft in line.

Two of these (2 and 5) require program preplanning and should be considered at this time.

a) Launch Without the Spacecraft - In multimission flights, consideration should be given at this time to providing either an adjustable mass/cg simulator to replace a given spacecraft, or enough flexibility in the system design to rearrange the spacecraft that will be flying so that mass/cg envelopes are met.

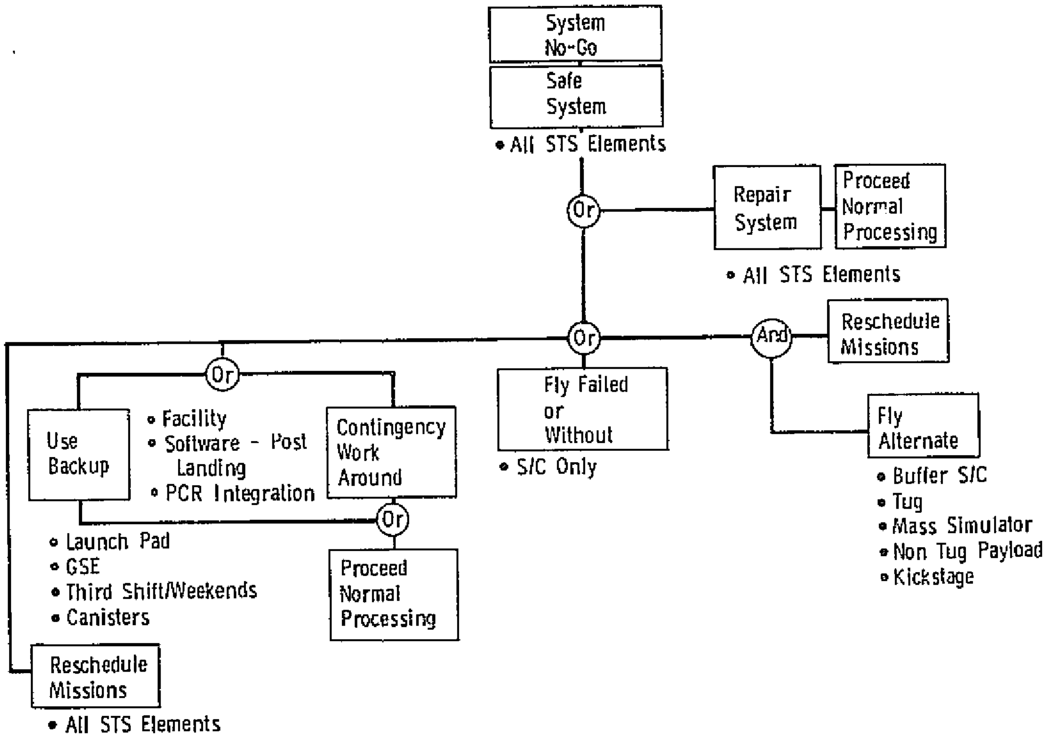


Figure III-B-1 Alternatives for System No-Go Contingencies

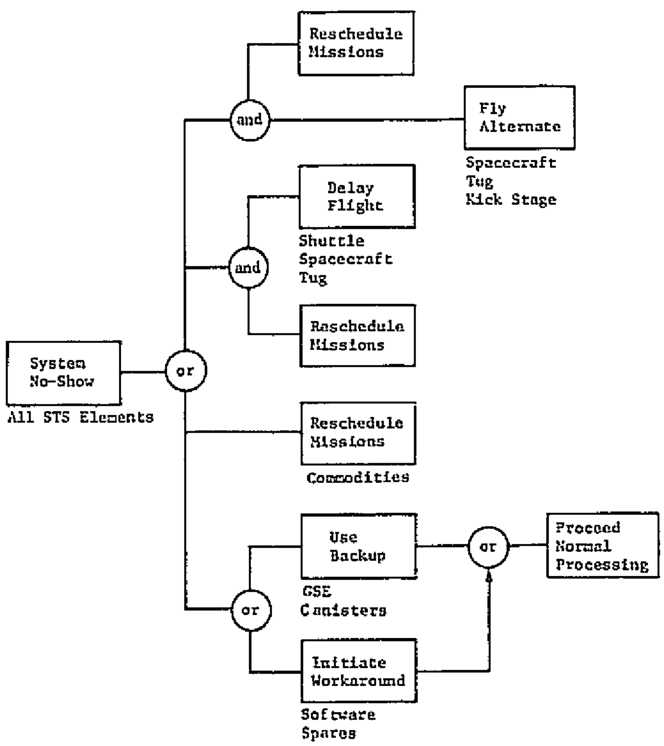


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Figure III-B-2
Alternatives for System No-Show Contingencies

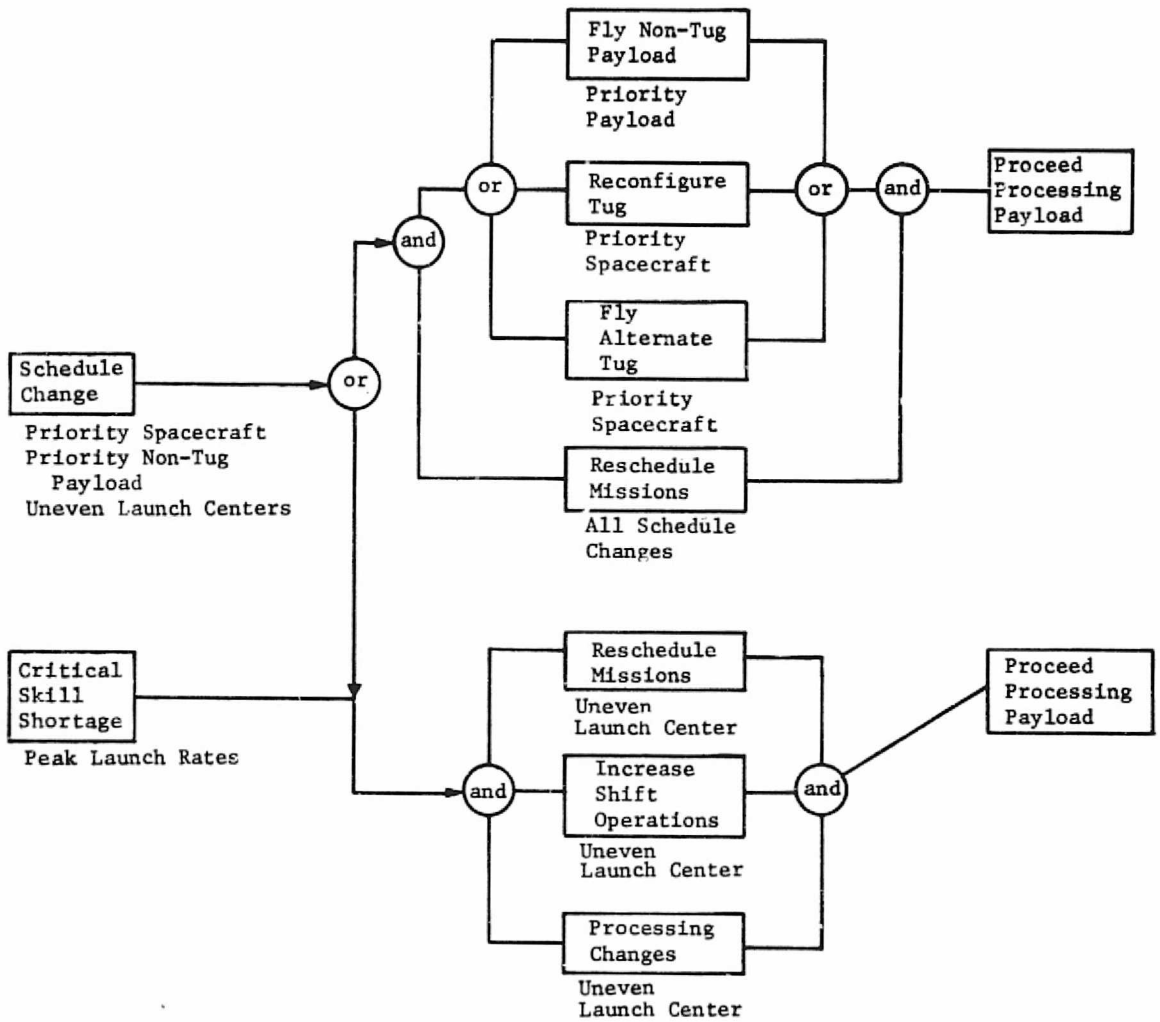

Figure III-B-3 Alternatives for Programmatic Contingencies

b) Provide Buffer Spacecraft in the Program - A buffer spacecraft is one presently in the mission model that may be made ready and available to launch ahead of its scheduled launch date as a substitute mission. Such a spacecraft would be available from an inventory of standby spacecraft or ahead of schedule to be ready to launch on short notice. The spacecraft selected would require certain workable characteristics. For example, simple integration, compatible launch windows, adaptable flight plans, compatible EMI and contamination and basically benign interfaces would be required. Designation of a few spacecraft as "buffers" on a preplanned basis may prevent major real time domino-type schedule perturbations as a result of spacecraft/spacecraft affected contingencies. One approach to attract such users would be to provide "reduced rates" to any potential user that meets the requirements and is willing to fly on a standby basis. Characteristics of the STS and Tug, such as standard interfaces, family of adapters, little SC to SC interface, make the buffer concept worthy of consideration.

3.1.2 Provide Flexibility in System Design to Accommodate Launch Date Variations - Several contingent situations can occur that can significantly affect Tug program schedules unless the system design has the flexibility to accommodate it: repair of no-gos, no-shows, off-nominal launch centers (between 5 and 10 days), priority payload changeout, increased launch rate, variations in flight mission duration (1 to 7 days), facility downtime, etc. Provisions in the system design that should be considered to provide flexibility against these contingencies follow.

a) Provide Additional Tug Checkout Cell in the TPF - The green light flow of Subplan A and the traffic model combine to dictate that only one Tug checkout cell is required in the TPF to handle all Tug flights. This is illustrated in Figure III-B-4. The figure shows that for uneven launch centers (5 days) or contingencies that tie up a Tug in the cell longer than scheduled, a second cell is required and should be provided.

b) Provide Additional GSE - Again, the green light flow of Subplan A and the traffic model combine to indicate that "one set" of GSE is required to accommodate all Tug flights and Figure III-B-5 bears this out. All but three GSE items are used less than 50% of the time during a Tug processing cycle (and all but five less than 30%) and the mean usage is less than 15%, giving ample flexibility for dual Tug usage for uneven launch centers down to about two days for most GSE items. The additional GSE sets which should be provided are those that have 50% (or greater) usage, or those that are time critical to processing should they fail. This includes:

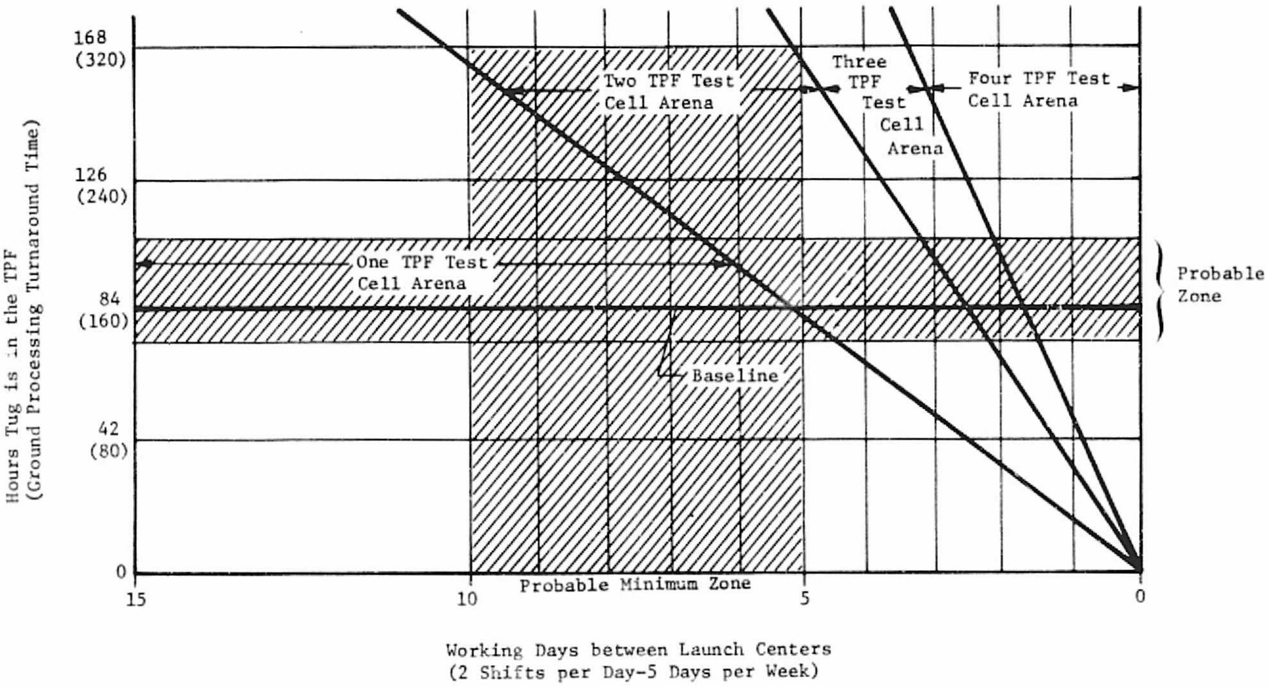

Figure III-B-4 Minimum Tug Checkout Cell Requirements in TPF

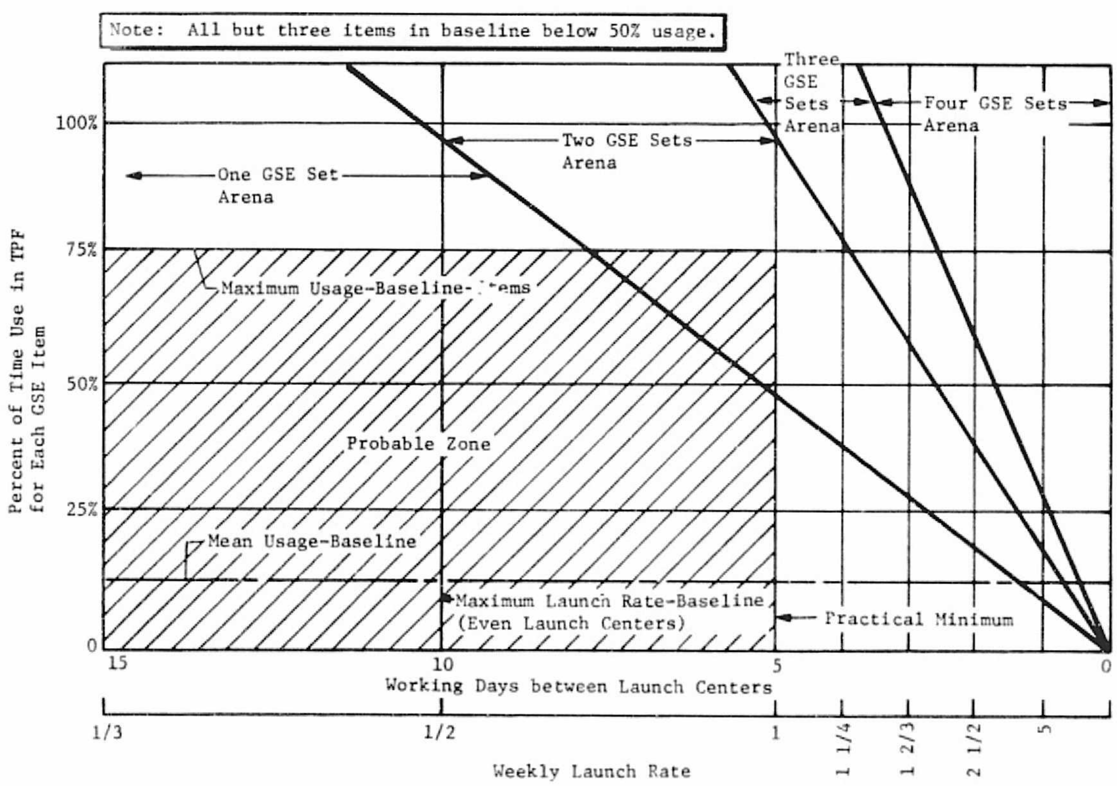

Figure III-B-5
Minimum Quantities of GSE in TPF to Satisfy Green Light Flow

1) Tug Workstand - H-001 - 50% usage. The stand is part of the checkout cell. Because of the high usage and because two checkout cells are recommended, two sets of workstands are recommended.

2) Inspection Workstands - H-026 - 50% usage. Two sets are recommended for the same reasons as 1).

3) Electrical Power Supply - A-001 - 50% usage. Two sets are recommended for the same reasons as 1).

4) Control and Data Acquisition Console - A-008 - about 30% usage. The console is integral to all Tug and systems testing and provides a primary interface with the LPS. The design of the console should incorporate capability to cycle two Tugs or provide an additional console as backup for uneven launch centers and console time critical failures.

5) Memory Load and Verify Unit - A-009 - about 30% usage. This unit is critical to launch schedules (loads Tug flight program) and should either incorporate functional redundancy in the basic design or have an additional backup unit in case of failure.

c) Increase Length of Work Week - The green light flow is based on a 5-day work week, two 8-hour shifts per day. Off nominal launch centers for short durations can be handled with the basic operations crew working 7 days, two 12-hour shifts per day. Figure III-B-6 illustrates the capability.

3.1.3 Provide Sufficient Redundancy in the System Design to Prevent Critical SFPs - Several elements in the system are critical to the timely processing of all Tugs, spacecraft, indeed the entire Shuttle vehicle, and should be designed to preclude critical single failure points (SFP) such as facility no-gos (propellant system, pressurization system, LPS, power system, launch pad, payload canister), GSE no-gos (general). The following criteria should be applied.

a) Provide Functional Redundancy in all Facility Commodity and Utility Systems - In the case of storable propellants, this requirement could be satisfied with a manual backup loading/unloading system. K bottles might backup the pressurization system. Two launch pads preclude a launch pad SFP incident. Functional paths in the power, LPS and cryogenic systems should be 100% redundant. Backup payload canisters will preclude that SFP.

Figure III-B-6

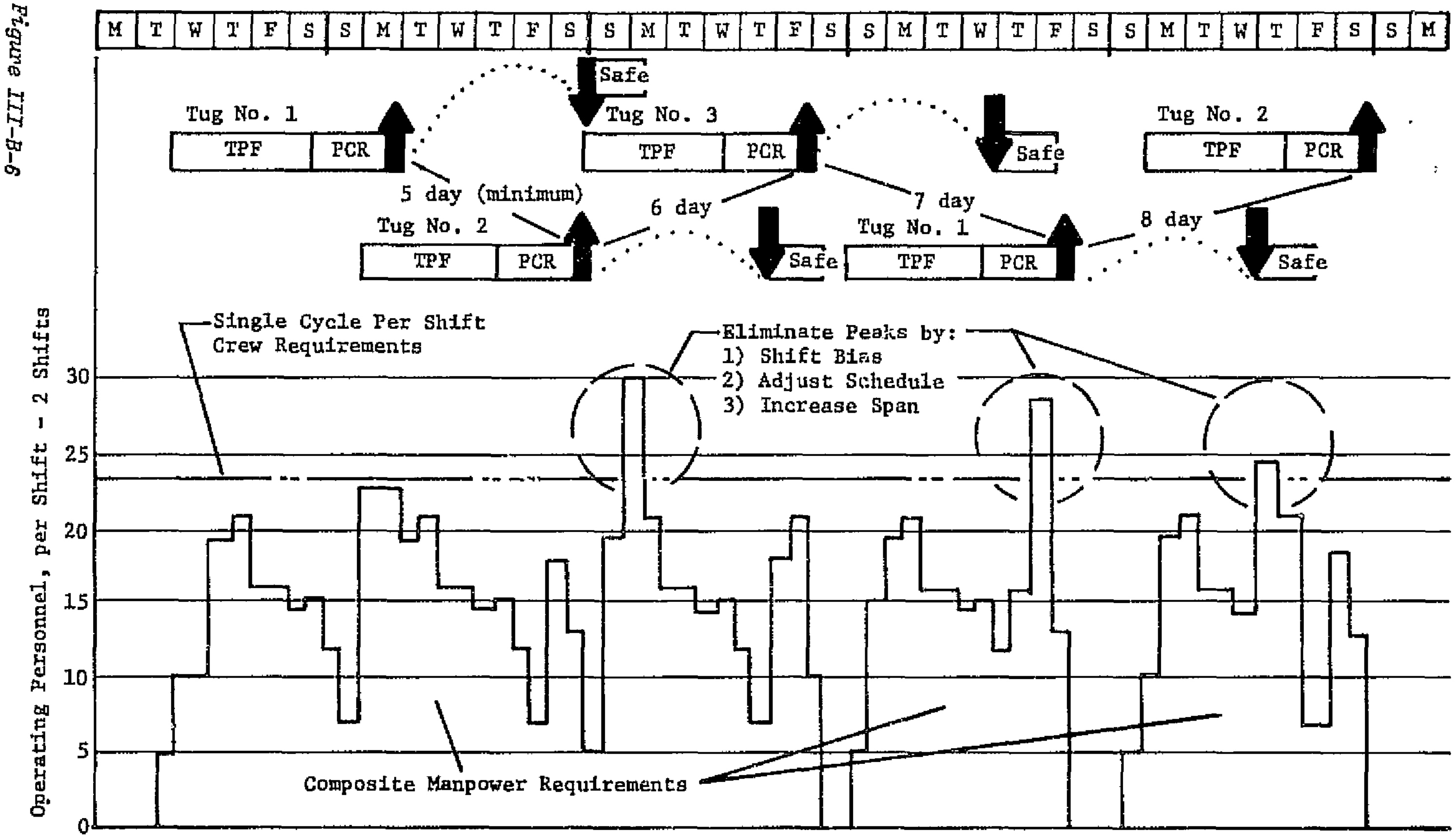

Figure III-B-6
ETR Operation, Uneven Launch Centers, Crew Requirements, 2-Shift; 7-Day Week

b) Provide Functional Redundancy in all GSE Hardware and Software Critical SFPs - The design of each critical functional item should include functional redundancy to the maximum practical extent. From a program point of view this means every item will be subject to analysis and every critical SFP in the design will be justified.

3.1.4 Provide a Backup Tug and Backup Kick Stages in the Active Fleet - The traffic model determines the minimum required active fleet size of Tugs and kick stages. To preclude major impacts to the schedule in the event of no-gos, no-shows of these vehicles, a spare or backup is recommended to be added to the active fleet size. It is noted that this does not impact the total fleet size, only the delivery schedule and facility space for storage.

3.1.5 Provide a Flexible Schedule and Control System - The overall management of the fleet is discussed in Program Controls, Section 4.0 of this subplan; however, it should be pointed out here the schedule and control system must be flexible enough to aid in contingency assessment and decision selection of alternative courses of action. Any system anomaly may impact the schedule, as will abnormal Tug attrition rates, abnormal Tug processing span times, mission changes, traffic model changes, and commodity shortages. The schedule and control system must identify the impact of such contingencies in real time, near real time, and in the planning stage to help determine feasible alternatives.

3.2 Facility and GSE Requirements Specification

The total facility and GSE requirements for the Tug program are defined in this section. The total requirements are a function of the single Tug processing cycle defined by the stick-and-ball chart in subplan A, the Tug traffic model or annual launch rate, WTR requirements, contingency provisions, and alternative contingency landing site provisions. The latter are specified as Edwards AFB, Hawaii, and Guam.

3.2.1 Facility Requirements - Table III-B-2 summarizes the total facility requirements for the Tug program and defines the source of the requirement. Detail requirements and specifications can be found in Appendix C in this report. It is noted that the current traffic and the alternative landing sites impose no Tug requirements on the facility. The WTR requirements are listed on one column of Table III-B-2.

Table III-B-2 Facility Requirements for the Space Tug, ETR and WTR

Facility \ Source of Requirement	Stick-and-Ball Chart (Ref subplan A and Appendix C) Processing of a Single Tug — Function	Requirement	Tug Traffic Model	ETR Contingency Provision	WTR Requirements
Orbiter Processing Facility, OPF at ETR	Offload Payload from Orbiter	Existing OPF transfer Aisle	No Additional Requirements	None	None
	Demate Tug/Spacecraft and Remove COMSEC Equipment	Single Cell, Controlled Access, LPS Terminal Available, H_2 Burner, Tug Hazardous Vapor Detection.			
Tug Processing Facility, TPF at ETR	Receive, Inspect, Safe, Clean Tug.	Airlock, Controlled Access, LPS Terminal, 100K* Class Clean, Personnel Safety Provisions.	No Additional Requirements	None	None
	Tug Refurbish, Checkout, Spacecraft Mate/Integration	Single Cell - Controlled Access, 100K* Class Clean, Tempest Compatible, Parasitic Antenna, LPS Terminal, OIS Communication.	No Additional Requirements	Add a Second Cell for Backup - Provision Identical to Single Cell.	None - WTR Launched Tugs Will Be Checked and Refurbished in ETR-TPF
	Tug Adapter Maintenance and Checkout	Single Bay - 100K* Class Clean, OIS Communication, LPS Terminal	No Additional Requirements	Add a Second Bay for Backup - Provision Identical to Single Bay.	None - Adapter for WTR Launched Tugs Will Be Checked in ETR-TPF.
	Kick Stage Buildup and Checkout	Single Bay - 100K* Class Clean, OIS Communication, LPS Terminal	No Additional Requirements	None	None - Kick Stages not Required at WTR
	Load Storable Propellants	Single Bay, 100K* Class Clean, OIS Communication, LPS Terminal, Controlled Access, Personnel Safety Provisions	No Additional Requirements	None	Facility Requirements at WTR Are Identical to ETR
	Store Tug and Adapter	Not Required	The Tug Traffic Model and Contingency Provisions Require Storage of Up to Four Tugs and Two Adapters in a Temperature and Humidity Controlled Environment.		None - No Storage of Tugs and Adapters Is Required at WTR
	Store Refurbishment Support Hardware	Temperature and Humidity Controlled, Storage Racks, Bins, and Shelves	No Additional Requirements	None	None - No Refurbishment Accomplished at WTR
	Subsystem Overhaul Refurbish, Maintenance and Checkout Areas	Controlled Access, 100K* Class Clean, LPS Terminals, Bench Calibration, Optical Alignment Platform.	No Additional Requirements	None	None - No Subsystem Work Done at WTR
	Load Tug and Spacecraft into Payload Canister	100K Class Clean Area, Controlled Access, OIS Communication	No Additional Requirements	None	WTR Requirements Identical to ETR Requirements
Payload Changeout Room, PCR at ETR (and Launch Complex)	Payload Transfer to Orbiter Bay	100K Class Clean Room, LPS Terminal, Device for Handling Tug and Installing it into Orbiter Bay (Vertical), Controlled Access, Tempest Compatible.	No Additional Requirements	Provide a Second PCR (and Launch Complex) Provide capability in Both PCRs to Changeout Entire Payload (Tug and Spacecraft) Spacecraft Only or Tug Only and Tug/Spacecraft Mate and Integration.	No Additional Requirements - ETR, Contingency Provisions Not Required
Launch Complex at ETR	Load Propellants and Pressurants	LH_2, LO_2, GHe Transfer and Vent Systems	No Additional Requirements	Provide a Second Launch Complex to Backup the First at ETR.	No Additional Requirements - No Backup Launch Pad Required
Orbiter Landing Field - OLF	No Tug Requirements				

*100K is baseline, factory clean is recommended.

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3.2.2 GSE Requirements - Table III-B-3 summarizes the GSE requirements for the Tug program with regard to facility location. Quantities, detail requirements and specifications can be found in Appendix B to this report. In general, the quantity of GSE defined to process a single Tug will suffice to satisfy total Tug program requirements because the usage rate of the equipment as a percentage of total processing time is very low (about 15% on the average). The exceptions are the GSE identified previously for which additional quantities are needed to combat contingencies, the GSE required at WTR, and the abort GSE. The GSE ID No. in the first column of Table III-B-3 refers to the identification code assigned to each piece of GSE for which a description sheet is provided in Appendix B.

3.3 Transportation Requirements and Support

The total transportation requirements for the Tug program include the single Tug Processing cycle requirements and additional quantities that contingency or launch rate requirements may impose. It includes the ferry requirements to transport a Tug and its support equipment from the manufacturer to KSC, from KSC to WTR, and from WTR to KSC, and from alternative contingency Orbiter landing sites (Edwards, Hawaii, Guam) to KSC, as well as onsite requirements at KSC and WTR.

The details of the operations for intersite and onsite transportation may be found in subplan A and in section 4.0 of this subplan. This section defines the total quantities of Transportation Support Equipment (TSE) required as a function of launch rate and contingencies.

3.3.1 TSE Quantity Requirements - The current traffic model (launch rate) imposes no quantity requirements on the TSE above and beyond single Tug requirements. The quantities identified in Table III-B-4 are due to contingencies: (1) alternate/contingency Orbiter landing sites and (2) motorized equipment backup. A backup canister is recommended to eliminate it as a source of a critical SFP (para III.B.3.1.3). The additional quantities of GSE (H-020 and H-019) are for Tug storage.

3.4 Operational Data (Instrumentation List) Requirements

Not Applicable to this Subplan.

3.5 Manpower Staffing Requirements

The total manpower staffing requirements for fleet utilization include the onsite personnel at ETR and WTR required to process the Tugs and offsite personnel who are required to manage the Tug fleet. The total crew requirement for managing and processing the Tug fleet is summarized as follows:

Table III-B-3 Ground Support Equipment Requirements

ID No.	GSE Nomenclature / Use Location	OLF-ETR Abort	OPF-ETR	TPF-ETR	WTR	OLF-WTR Abort	Contingency OLF-Abort
	<u>Avionics</u>						
A-001	Electrical Power Supply*		x	x	x		
A-002	Electrical Power Test Set			x			
A-003	Electrical Load Banks			x			
A-004	Battery Test Set			x			
A-005	Battery Charger			x	x		
A-006	Communication Test and Checkout Equipment			x			
A-007	Guidance and Navigation Test and Checkout Equipment			x			
A-008	Control and Data Acquisition Console*		x	x	x		
A-009	Memory Load and Verify Unit*			x	x		
A-010	Electronics Calibration Equipment			x			
A-011	Orbiter Cable Simulator			x	x		
A-012	Umbilical Simulator			x	x		
A-013	Star Sensor Simulator			x			
A-014	Tug/Spacecraft Simulator			x			
A-015	Fuel Cell Dummy Load Unit			x			
A-016	Ordnance Event Verification Cables			x	x		
A-017	Latch Mechanism Test Set			x			
A-018	Hardware Interface Module			x	x		
	<u>Propulsion and Mechanical</u>						
P-001	Aft Umbilical Servicing Unit	x		x	x	x	x
P-002	Fuel Cell GN_2 Purge Unit			x	x		
P-003	Fuel Cell Water Supply Unit			x			
P-004	Fuel Cell GH_2 Accumulator Charge Unit			x			

* Additional quantities required for contingencies at ETR only.

Table III-B-3 (cont)

ID No.	Use Location / GSE Nomenclature	OLF-ETR Abort	OPF-ETR	TPF-ETR	WTR	OLF-WTR Abort	Contingency OLF-Abort
P-005	Fuel Cell GO_2 Accumulator Charge Unit			x			
P-006	Engine Alignment Kit			x			
P-007	Tug Engine Actuator Servicing Kit			x			
P-008	Alignment Kit			x			
P-009	Insulation Purge and Metering Unit			x	x		
P-010	Propellant Supply and Transfer Unit			x			
P-011	APS Propellant Control Set			x	x		
P-012	APS Propellant Supply and Transfer Unit			x	x		
P-013	Preservation Unit			x			
P-014	Vacuum Pump and Gauge Unit			x			
P-015	Hydraulic Servicer			x			
P-016	Pressurization Control Set			x	x		
P-017	Decontamination Unit APS			x			
P-018	Vacuum Pump and Gauge Unit APS			x	x		
P-019	Thermal Control Servicing Set			x			
P-020	Hot GN_2 Purge Unit			x			
	<u>Structural</u>						
S-001	Ultrasonic Scan Unit			x			
S-002	Radiography Unit			x			
	<u>Handling and Transportation</u>						
H-001	Tug Workstand*			x	x		
H-002	Engine Workstand			x			
H-003	Deployment Adapter Workstand			x			
H-004	Tug Transportation Dolly			x			
H-005	Cargo Bay Work Platform Set		x		x		

* Additional quantities required for contingencies at ETR only.

Table III-B-3 (concl)

ID No.	Use Location / GSE Nomenclature	OLF-ETR Abort	OPF-ETR	TPF-ETR	WTR	OLF-WTR Abort	Contingency OLF-Abort
H-006	Internal Platform			x			
H-007	Deployment Adapter Dolly			x			
H-008	Deployment Adapter Protective Cover Kit			x			
H-009	Spacecraft Adapter Transport/ Storage Pallet			x			
H-010	Kick Stage Protective Cover Kit			x			
H-011	Kick Stage Motor Cradle			x			
H-012	Kick Stage Buildup/Checkout Fixture			x			
H-013	Kick Stage SRM Storage Pallet			x			
H-014	Kick Stage Storage Pallet			x			
H-015	Tug Storage Pallet			x			
H-016	Tug Engine Handling Kit			x			
H-017	Deployment Adapter Storage Pallet			x			
H-018	Handling Sling Kit		x	x	x		
H-019	Tug Protective Cover Kit		x		x		
H-020	Tug Desiccant Kit			x			
H-021	Battery Handling Kit			x	x		
H-022	Air Carry Tie Down Kit			x	x		
H-023	Transport Data Recorder			x			
H-024	Tug Transtainer		x	x	x		
H-025	Tug Lifting Rings		x	x	x		
H-026	Inspection Workstands*		x	x	x		
H-027	Spacecr_ft Docking Simulator			x			
H-028	Kick Stage Transtainer			x			
H-029	Vertical Adapter				x		
H-030	Kick Stage Motor Support			x			

* Additional quantities required for contingencies at ETR only.

Table III-B-4 Tug Transportation Support Equipment (TSE) Requirements

<table>
<tr><th rowspan="3">Equipment Source</th><th rowspan="3">Item</th><th colspan="8">TSE Location Requirements</th><th rowspan="3">Qty for Single Tug</th><th rowspan="3">Launch Rate or Contin-gency Qty</th><th rowspan="3">Total Qty</th></tr>
<tr><th colspan="2">Between KSC & WTR</th><th colspan="2">Between MFGR & KSC</th><th colspan="2">Between OLF & KSC</th><th rowspan="2">Onsite KSC</th><th rowspan="2">Onsite WTR</th></tr>
<tr><th>KSC</th><th>WTR</th><th>MFGR</th><th>KSC</th><th>OLF</th><th>KSC</th></tr>
<tr><td>Motor Pool or Contractor</td><td>Prime Mover</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>2</td><td>3</td><td>5</td></tr>
<tr><td>TSE/GFE*</td><td>Transporter, Canister</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>2</td><td>3</td><td>5</td></tr>
<tr><td>TSE/GFE*</td><td>Payload Canister</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td>X</td><td>X</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Facility and Contractor</td><td>Overhead Crane</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td>X</td><td>3</td><td>0</td><td>3</td></tr>
<tr><td>GSE</td><td>Hoisting Sling Kit - ID No. H-018</td><td>X</td><td>X</td><td>X</td><td>X</td><td colspan="2">X</td><td>X</td><td>X</td><td>3</td><td>0</td><td>3</td></tr>
<tr><td>TSE/GFE*</td><td>Mate/Demate Fixture (MDF) and Support Kit</td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>TSE/GFE*</td><td>747 Aircraft</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td></td><td></td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>TSE/GFE* or Contractor</td><td>Mobile Crane</td><td></td><td></td><td>X</td><td></td><td>X</td><td></td><td></td><td></td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>TSE/GFE*</td><td>Storage Dolly</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td>3</td><td>0</td><td>3</td></tr>
<tr><td>TSE/GFE*</td><td>Canister/747 Attach Kit</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td></td><td></td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>GSE</td><td>Transportation Instrumentation Kit - ID No. H-023</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td>X</td><td>X</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>GSE</td><td>Tank Breather Set - ID No. H-020</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td>X</td><td>X</td><td>2</td><td>3</td><td>5</td></tr>
<tr><td>GSE</td><td>LH_2 Tank Dome Cover - ID No. H-019</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td>X</td><td>X</td><td>2</td><td>3</td><td>5</td></tr>
<tr><td>GSE</td><td>Tug Tie Down Kit - ID No. H-022</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td>X</td><td>X</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>TSE/GFE*</td><td>Canister to 747 Aircraft Attach Kit</td><td colspan="2">X</td><td colspan="2">X</td><td colspan="2">X</td><td>X</td><td>X</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td colspan="13">*TSE/GFE - Shuttle and/or Payload Provided - Multiuse-Equipment</td></tr>
</table>

Onsite Personnel (ETR and WTR) = 114

Fleet Management Personnel (offsite) = 85

Total Personnel Required = 199

This number is the maximum estimate for the operational duration of the program as some of the functions, such as sustaining engineering and training, will undoubtedly taper off in later years.

The individual manpower requirements are discussed in the following paragraphs.

3.5.1 Single Tug Processing Cycle Requirements - Subplan A indicates a total crew requirement of 80 people for a two-shift-per-day, five day work week. Approximately 60% of that total is directly related to processing the Tug, while the other 40% covers support people, such as Facilities, Engineering, offline technicians and supervision/management whose numbers are generally independent of the launch rate. Therefore, only those directly processing Tugs, or about 30% of the total, would be affected by launch rate and uneven mission duration, etc.

3.5.2 Total ETR Crew Requirements - The current traffic model indicates a maximum Tug launch rate of 26 per year or one every two weeks. Figure III-B-7 indicates that the single processing crew can handle launch rates of 26 per year based on even launch centers. Figure III-B-6 shows that the same crew can handle uneven launch centers down to five days (from 10 days) by going to a seven-day per week/two 12-hour shifts per day work week. The conclusion is that the 80-man single cycle crew requirement is sufficient for all ETR operations.

3.5.3 Total WTR Crew Requirements - The current traffic model indicates a maximum WTR Tug launch rate of two per year and only one per year in five of the eight Tug program years. The single Tug processing cycle would indicate a need for approximately 80 people at WTR were the Tug to be processed there. However, because of the extremely low launch rate and common Tug checkout facility philosophy, only a small group of liaison people need be permanently situated at WTR. Typically, this organization would be as shown in Figure III-B-8. The Tug processing crew and main support crew will accompany the Tug from ETR to launch it and return it to ETR. Figure III-B-9 is a WTR stick-and-ball chart showing the number of personnel required to do this processing; the total is 34 based on one-shift operations. With the seven permanent people, a total complement of 41 people is a WTR requirement. Figure III-B-10 shows the composite ETR/WTR organization for the WTR requirements. With two-shift operations at WTR, the required crew at WTR, extrapolated from Figure III-B-9, is 50.

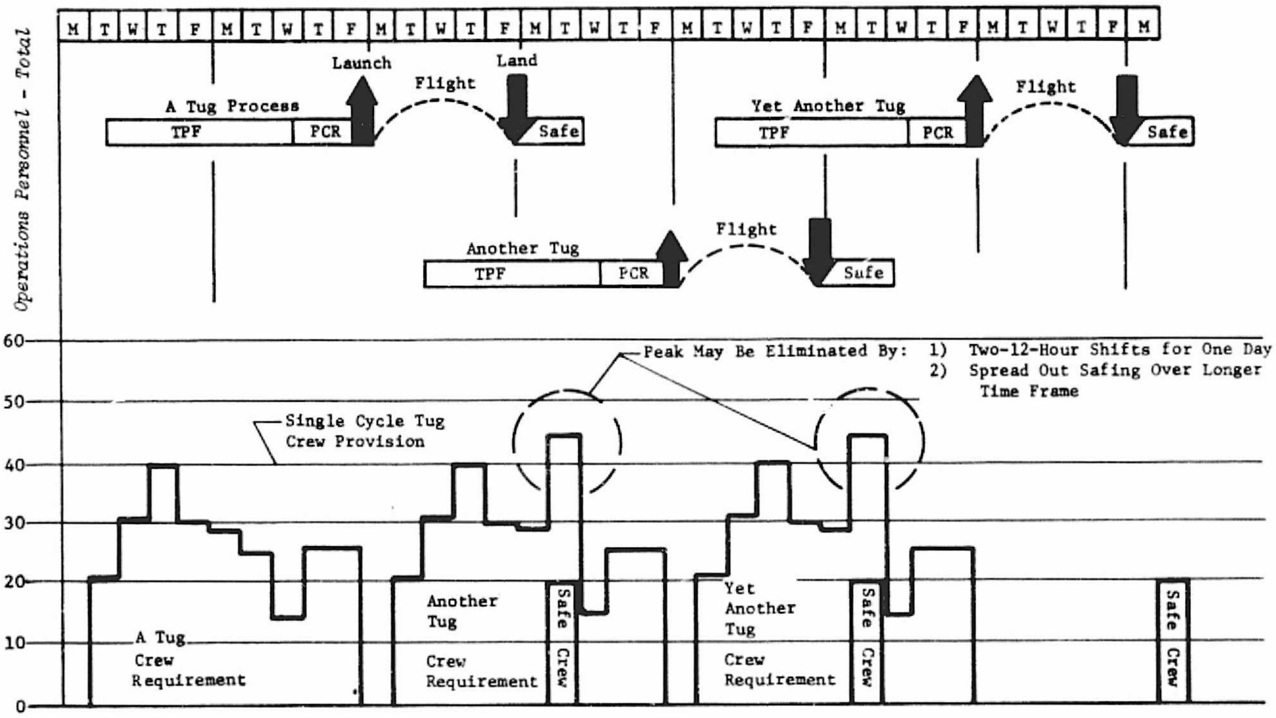


Figure III-B-7
ETR Operations - Maximum Launch Rate - Even Launch Centers - Crew Requirements

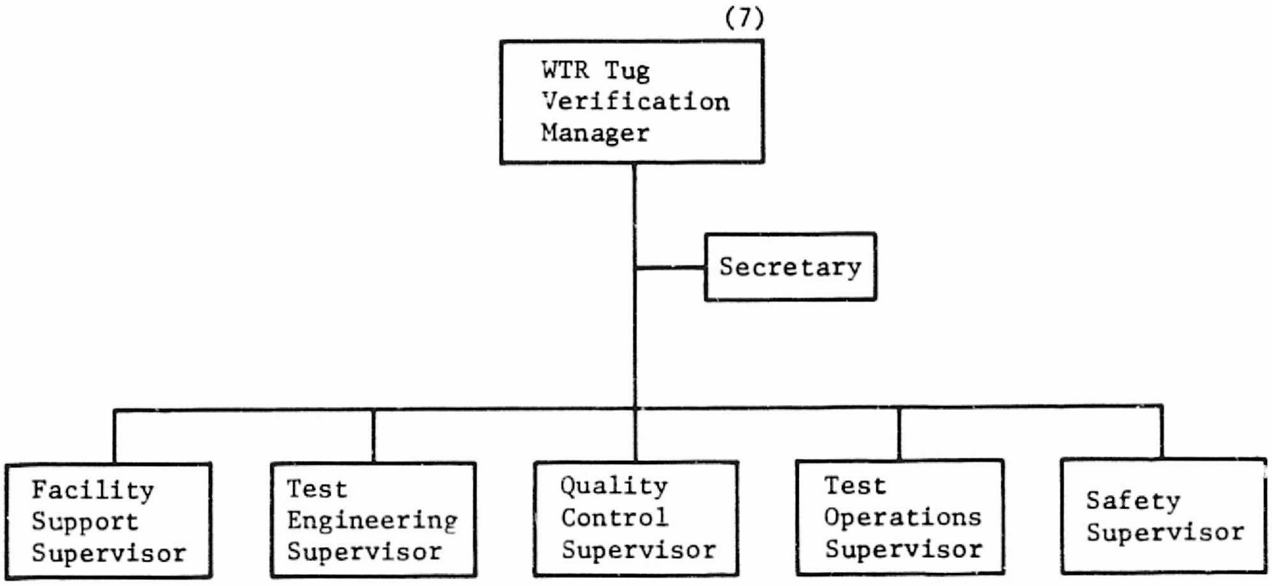


Figure III-B-8 WTR Permanent Launch Site Operations Crew

Shift	1												2				(Day)				3(1)				4(2)							
Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

PREPARE TO SHIP 4.4.9 — MOVE TO SHUTTLE AIRFIELD — LOAD ON AIRCRAFT 4.51 — FLYING TIME TO WTR — UNLOAD FROM AIRCRAFT 4.1 — MOVE TO PCU 5.22 — RECEIVING INSPECTION 4.4 — SYSTEMS HE[ALTH] EVALUATION — PAR[T] PRE[S]

ETR ← | → WTR

LOAD

FLY 32 ETR PEOPLE TO WTR

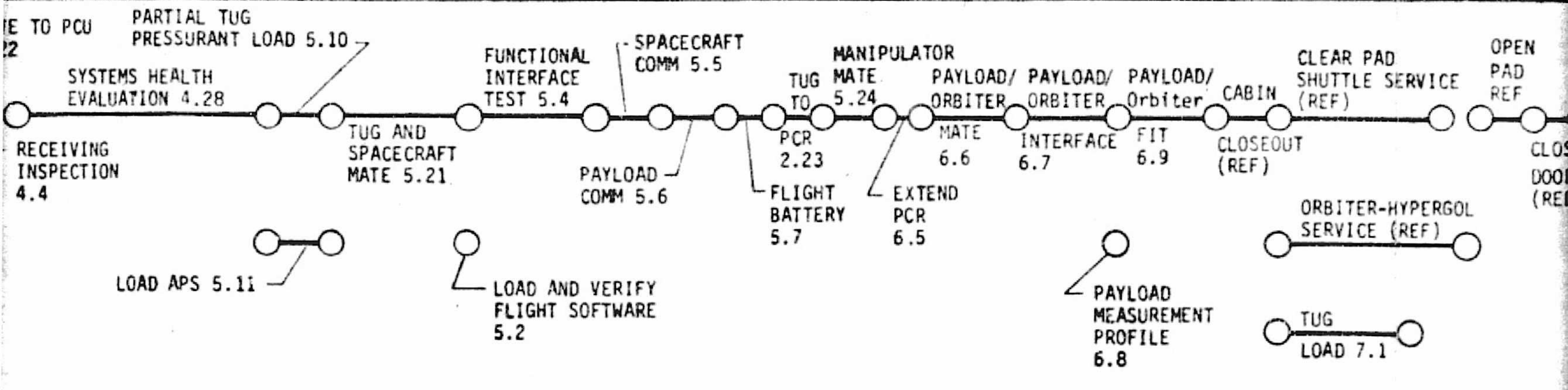
NOTE: KICK STAGES NOT REQUIRED AT WTR.

2 PEOPLE FLY WITH TUG

→ ETR PEOPLE AT WTR (EXCEPT MANAGEMENT SUPPORT)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
TOTAL MANPOWER	30	30	30	30	26	26	26	26	14	14	14	14	2	2	2	2	2	2	2	2	21	21	21	21	23	25	25	31	31	31	31	31
TEST CONDUCTOR																												1	1	1	1	1
TEST ENGINEER	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			2	2	2	2	2
PROPULSION TECHNICIAN																										1	1	2	2	2	2	2
STRUCTURE/MECHANICAL/THERMAL TECH	3	3	3	3																					2	1	1	1	1	1	1	1
AVIONICS TECHNICIAN	1	1	1	1																						1	1	3	3	3	3	3
SAFETY ENGINEER	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1
QC TECHNICIAN																										3	3	2	2	2	2	2
TECHNICAL SUPPORT	8	8	8	8	8	8	8	8	3	3	3	3									6	6	6	6	6	6	6	6	6	6	6	6
MANAGEMENT SUPPORT	8	8	8	8	8	8	8	8	1	1	1	1									7	7	7	7	7	7	7	7	7	7	7	7
FACILITY SUPPORT	8	8	8	8	8	8	8	8	8	8	8	8									6	6	6	6	6	6	6	6	6	6	6	6

FACILITIES	TPF-ETR	SLA-ETR		SLA-WTR	PCU	
GSE	P-013 H-019 H-020 H-022	H018			H-019 H-018 H-025 H-029	A-001 A-008 A-009
TSE	PRIME MOVER-TRANSPORTER CANISTER-MDF-747 AIRCRAFT →				PRIME MOVER, CANISTER	
SOFTWARE	NONE					LPS SOFTWARE



TR
ENT SUPPORT)

PRELA
PERSO
AT WT

4(2)					5(3)								6(4)								7(5)		
28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
31	31	31	31	31	31	31	31	32	32	25	25	25	25	31	31	31	31	25	25	24	24	24	26
1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1		
2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2	2	1	1	1	1	1	1
2	2	2	2	2	2	2	2	4	4					1	1	1	1						
1	1	1	1	1	1	1	1			2	2	2	2	1	1	1	1					1	3
3	3	3	3	3	3	3	3	2	2	1	1	1	1	4	4	4	4	2	2	1	1	1	1
1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2	2	1	1	1	1	1	1
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

7(5)					8(6)								9(7)								10(	
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
23	23	21	29	29	32	32	32	32	32	31	31	31	20	20	29	29	29	29	22	22	22	22
1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		1	2	2	2	2	2	2	2	2	2	2			2	2	2	2	2	2	2	2
			1	1	3	3	3	3	3	2	2	2			4	4	4	4				
2	2		2	2																		
			1	1	4	4	4	4	4	4	4	4			1	1	1	1				
1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1				
			2	2	2	2	2	2	2	2	2	2			1	1	1	1				
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

PCR | LAUNCH PAD | IN ORBITER

A-001 A-008 A-009 | A-003 P-011 P-012 P-016 | A-001 P-008 A-017 | A-001 A-008 ...-009 A-012 A-011 H-021 | H-018 H-030 | NONE

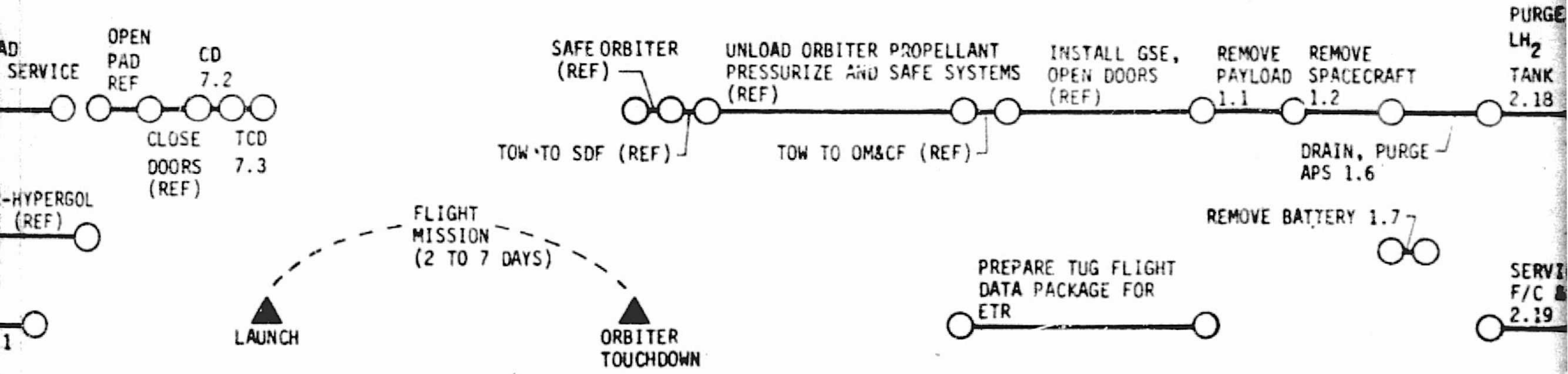
OV... R | PCR MANIPULATOR | NONE

LPS SOFTWARE | LPS SOFTWARE FLIGHT SOFTWARE | NONE | LPS SOFTWARE

PAGE IS
QUALITY
FOLDOUT FRAME 2

FOLDOUT

				10(8)					
	70	71	72	73	74	75	76	77	



FLY 18 PEOPLE BACK TO ETR

PRELAUNCH-TOTAL PERSONNEL REQUIRED AT WTR

29	22	22	22	22	22	30	25	41
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	3	3	5*
4						3		4
								3
1						2		4
1						1	1	2
1						1	1	3
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6

POSTLAUNCH TOTAL PERSONNEL REQUIRED AT WTR

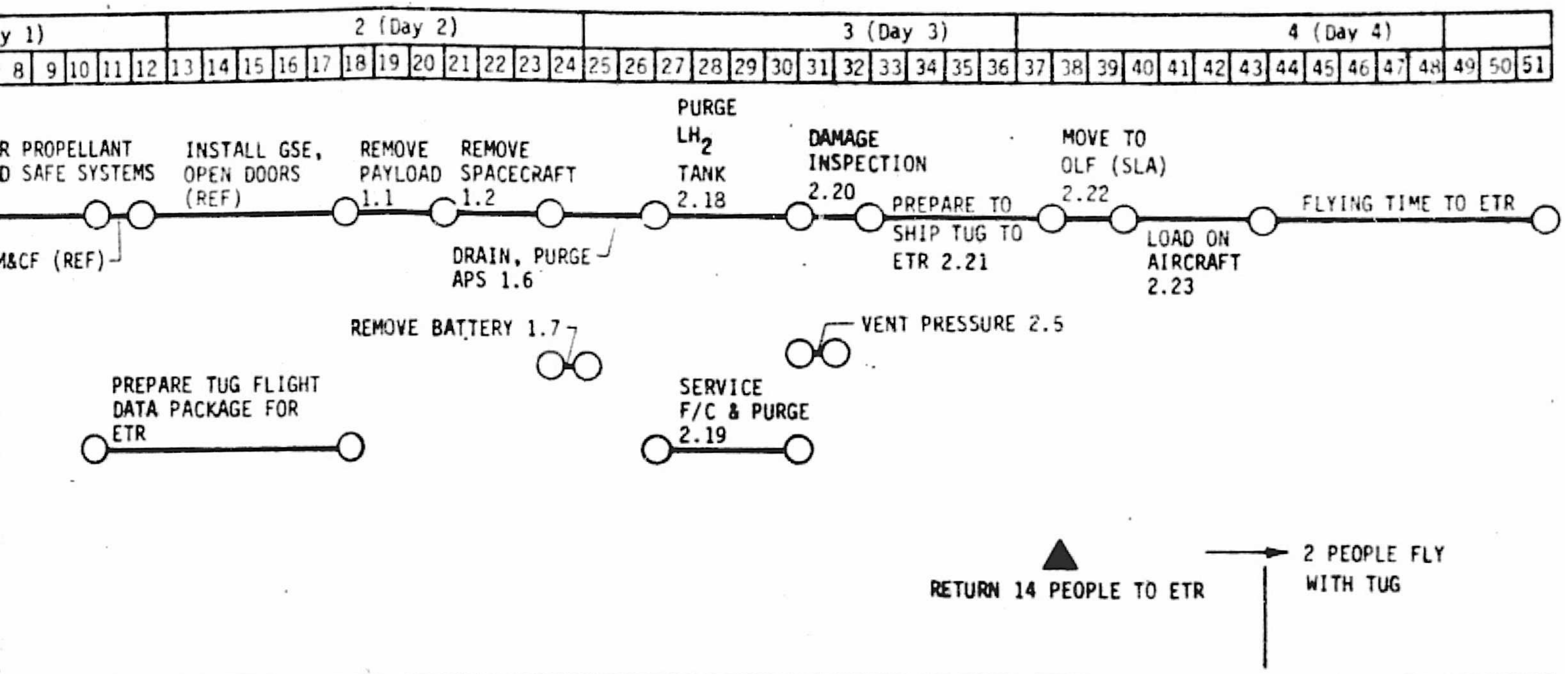
SHIFT	1 (Day 1)												2 (Day 2)															
HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
23	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	11	11	12	12	12	12	14	12	12	17	17
0																												
3	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	2	2
4																								2	2	2	4	4
3																		3	3	3	2	2	2					
2																								2			2	2
2																				1	1	1	1	1	1	1	2	2
2	1	1	1	1	1	1	1	1	1	1											1	1	1	1	1	1		
0																												
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
0																												

WTR RUNWAY	SAFING AND DESERVICING FACILITY	ORBITER MAINTENANCE AND CHECKOUT FACILITY		
NONE		H-018 H-005 H-019 H-030 H-025 H-029	H-021 A-001 A-008 P-011 P-016	P-016 P-002
NONE				
			NONE	

*TEST ENGINEERS DISCIPLINE ORIENTED - NEED EACH DISCIPLINE THROUGHOUT PROCESSING CYCLE - THROUGH LAUNCH

Figure III-B-9 WTR Tug Operati

FOLDOUT FRAME 3



8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
9	9	9	10	10	10	10	10	10	10	11	11	12	12	12	12	14	12	12	17	17	17
1	1	1	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	2	2	2
																2	2	2	4	4	4
										3	3	3	2	2	2						
																2			2	2	2
												1	1	1	1	1	1	1	2	2	2
1	1	1											1	1	1	1	1	1			
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
17	18	14	13	13	13	13	13	9	9	9	9	9	9	2	2	2	2	2	2	2	2
2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	4	2																			
	2	2	3	3	3	3	3														
2	1	1	1	1	1	1	1														
2			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1																			
7	7	7	7	7	7	7	7	7	7	7	7	7	7								

ND
ING

ORBITER MAINTENANCE AND CHECKOUT FACILITY

OLF (SLA)

E

H-018 H-005
H-019 H-030
H-025
H-029

H-021
A-001
A-008
P-011
P-016

P-016
P-002

P-016

H-018
H-019
H-024

H-018

CANISTER

MDF-747 AIRCRAFT

PRIME MOVER-CANISTER

NONE

Figure III-B-9 WTR Tug Operations Timeline Resource Requirements (Green-Light Flow)

3.5.4 Total Crew Requirements for ETR and WTR Operations - Figure III-B-11 depicts the total ETR and WTR operations crew requirements. By adding the peaks of the operations crew requirements and the support personnel requirements, a total of approximately 114 people are required with 7 of those stationed permanently at WTR. This crew requirement is based on a one shift per day operation at WTR. Figure III-B-12 gives the totals with a two shift per day operation at WTR, indicating a total of 119 people. This total can be reduced by approximately 10 people by shift adjustments and overtime, leaving a total of 114 people for planning purposes as follows: ETR - 107, WTR - 7. It is recognized that uneven launch centers at ETR during a WTR launch would increase the manpower requirements by about 20%; however, it has not been planned because of the infrequency of WTR launches.

Finally, a typical ETR organization with WTR launch capability is shown in Figure III-B-13.

3.5.5 Manpower Required to Manage the Tug Fleet - Several functions are involved in managing the fleet--cost/performance management, project direction, information management, fleet utilization planning management, sustaining engineering, logistics management, and software management. Each of these functions requires a staff of people and mechanized systems as defined in Program Control System, Section 4.0 of this subplan. Figure III-B-14 depicts a typical organization of 85 people required to manage the fleet. The functional responsibilities of the manpower follow.

3.5.5.1 Cost/Performance Management Manpower - This activity assures the integrated planning, scheduling, budgeting, work authorization, and cost accumulation of all ground operations tasks performed during the Tug program. It also includes project performance planning, preparation, and maintenance of the Project Management Plan, project schedules, resource status reports, change controls, data summary analysis, procurement management, and safety management.

Typically, this organization would consist of a manager, planners, budget controllers, timekeepers, and report writers. No analysts or programmers are included as that function can be time-shared with fleet utilization.

3.5.5.2 Project Direction Manpower - This small group continuously monitors all functional management disciplines to provide central direction and control of the overall operations project, including decision-making for management, problem resolution to meet schedules, overall project surveillance/control, and configuration control.

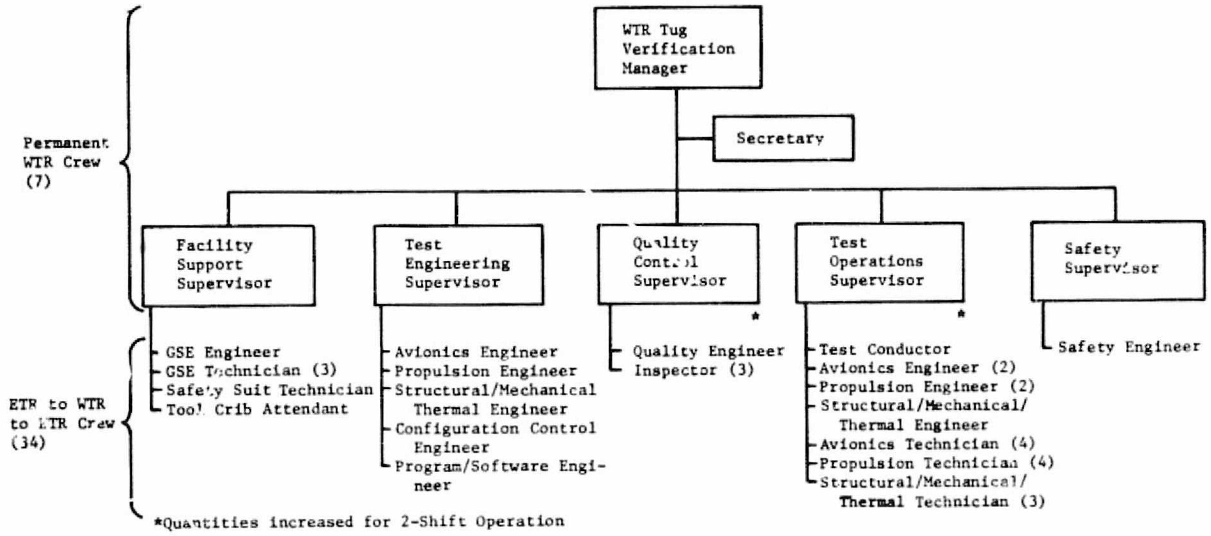


Figure III-B-10
Composite Crew Organization for WTR Requirements - One Shift Operations

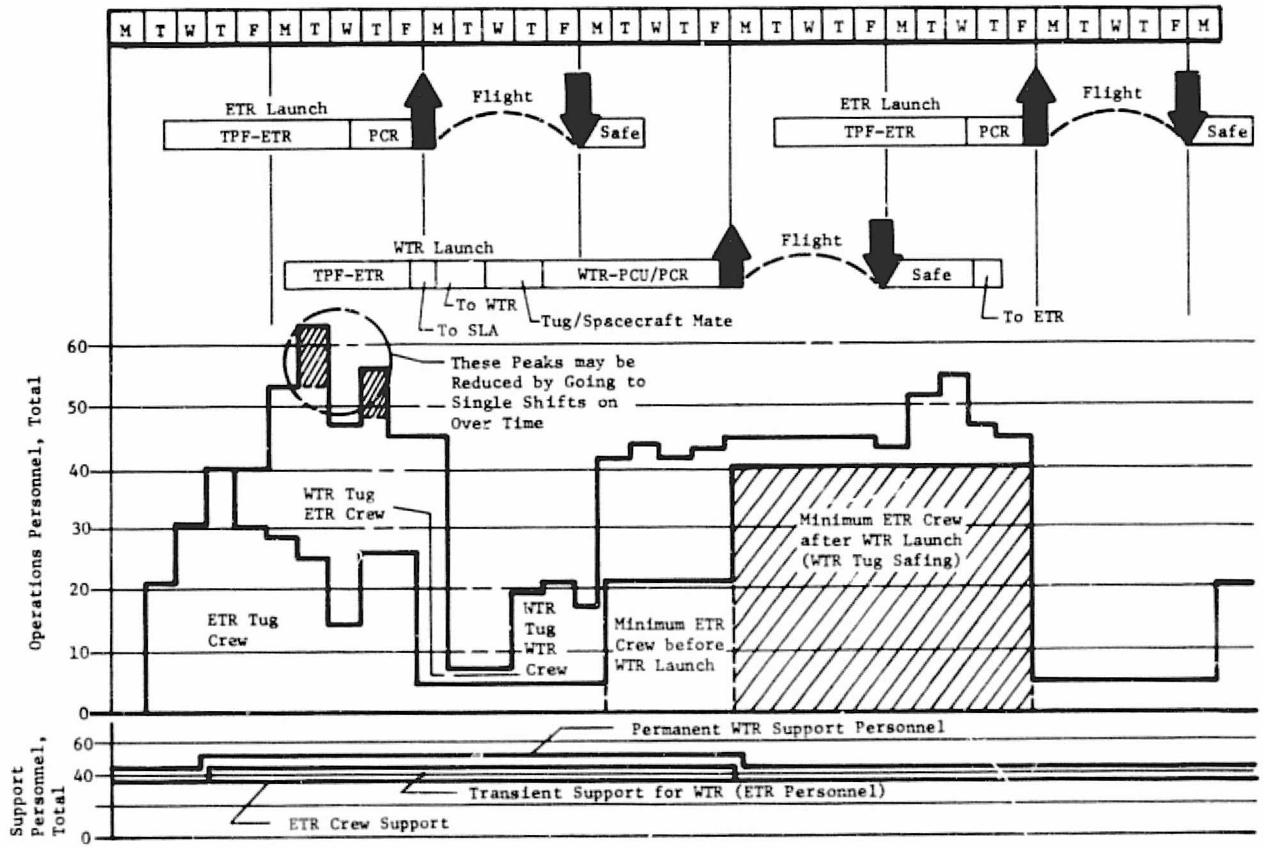


Figure III-B-11
Crew Requirements for ETR and WTR Operations - One Shift Operation at WTR

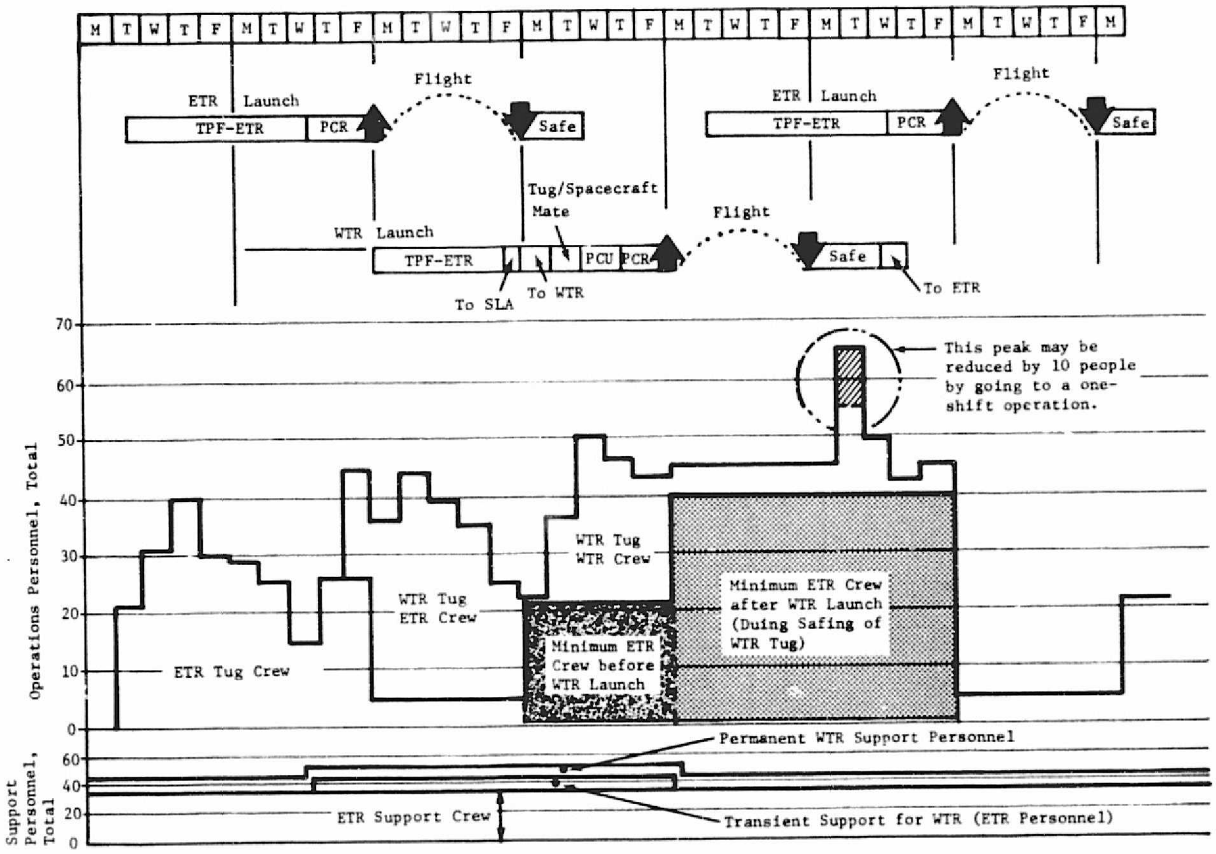


Figure III-B-12
Crew Requirements for ETR and WTR Operations - Two Shift Operation at Both Sites

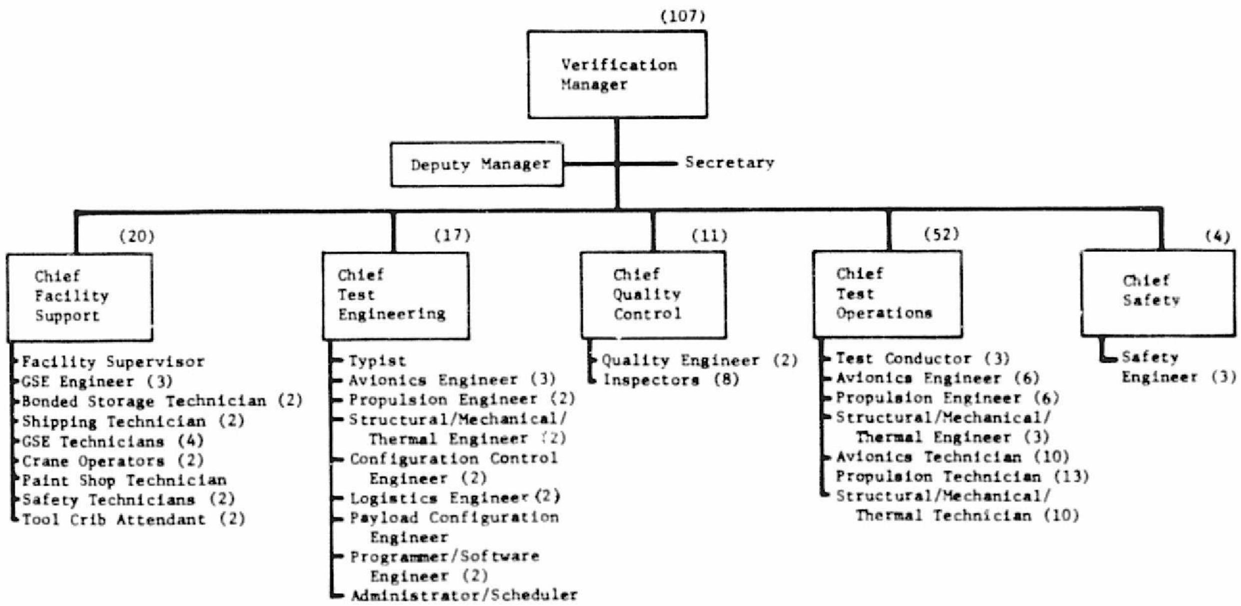


Figure III-B-13 ETR Crew Organization (With WTR Launch Capability)

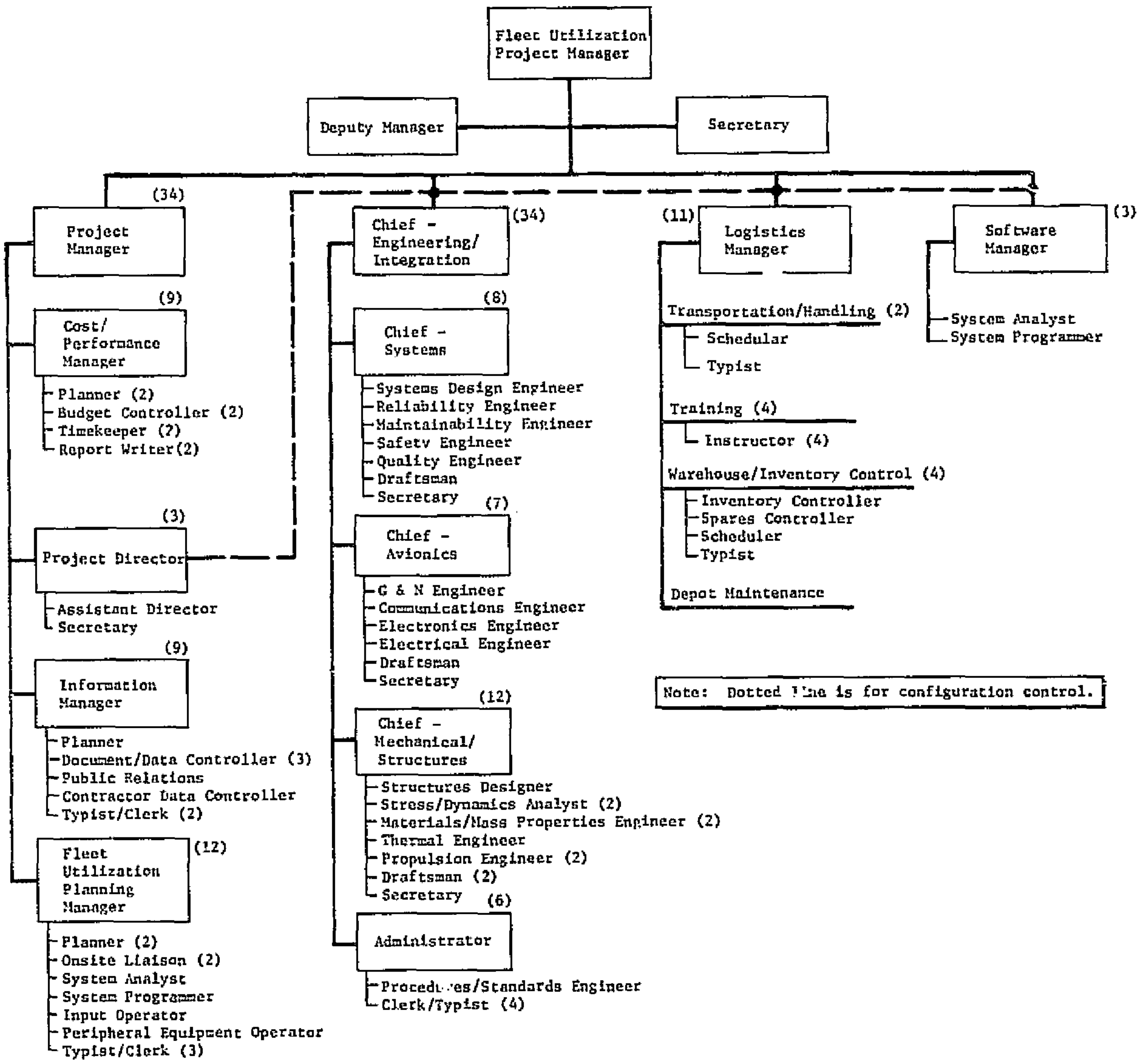


Figure III-B-14 Fleet Utilization Management Organization

3.5.5.3 *Information Management Manpower* - This group provides project visibility to the overall management process and their activities to ensure proper information and documentation flow and control. Included are information coordination; identification, control and monitor of the preparation and maintenance of documentation; establishment, implementation and maintenance of a Data Management Plan and Procedures; acquisition of data from subcontractors, vendors and others; preparation, maintenance and submittal of the data, data schedules, and accession list; establishment, operation, and maintenance of a project level information file and management information center(s). These functions require planners, document/data controllers, contractor (sub and vendors, too) data controller, and typists/file clerks. Should more than one management information center be provided, the manpower would increase.

3.5.5.4 *Fleet Utilization Manpower* - This group does the planning perparation and updating of the ground operations (launch operations and refurbishment and integration) part of the ground and flight operations fleet utilization plan for all Tug missions in the detail required for project management, including all hardware and software functions required to provide the ground operations part of a mechanized Tug fleet utilization planning system.

Preparation and updating of the fleet utilization plan for ground operations using the mechanized fleet utilization planning system include: (1) preparation of the Tug fleet utilization ground operations plan based on mission planning data, Tug turnaround timelines, desired launch dates, and mission priorities; (2) conduct of schedule studies and contingency analyses to establish schedule alternatives for advanced planning and contingencies (for allocation of Tugs and payloads to near-term missions that can meet the turnaround timelines; for maintenance requirements for each Tug; and for availability of each payload as it is progressively defined and scheduled through the LPS); and (3) updating the Tug fleet utilization plan as directed by project management.

The hardware function includes furnishing and maintaining the computer peripheral equipment and communication links dedicated to ground operations that are required to input and process the data and display the current ground operations part of the fleet utilization plan and status; the software function provides for the development, integration, and maintenance of the Tug fleet utilization planning system software for ground operations. Integration includes interfacing GSE software and hardware.

Organizationally, these functions typically would include manager, planners, onsite liaison people, system analyst, system programmer, input operator (e.g., keypunch), peripheral equipment operator, and typist/clerk. It is noted that the hardware/software portion of this organization would undoubtedly do the computer work for the other business organizations of fleet management such as cost/performance, information, and logistics.

3.5.5.5 *Sustaining Engineering Manpower* - These people provide project management sustaining engineering effort required for the Tug and ground operations. A principal effort includes normal product improvement and engineering changes that may occur as a result of user recommendations and/or operational experience. Also included are in-plant engineering liaison support required at the launch sites during the operations phase. Activities would include further evaluation of vehicle and GSE performance, maintainability analysis, transportation, and handling requirements, etc.

This group would cover the technical disciplines: structures, thermal, avionics, communications, electronics/electrical, propulsion, mechanical, systems design, reliability, maintainability, safety, quality, managers, administrator, secretaries, and clerk/typist.

This group participates in configuration control, directing and controlling a ground operations integrated engineering effort, including requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability, maintainability, configuration management, quality engineering, and technology utilization.

3.5.5.6 *Logistics Management Manpower* - This group will implement, operate, and maintain a logistics management for support of the Tug and its related ground support equipment, including transportation and handling, warehousing, training of ground crew personnel and depot maintenance.

Transportation and handling management includes the fleet ground operations and control management activities of planning, organizing, directing, coordinating, and controlling the effort between the launch sites and various contractor maintenance depots for hardware modification and scheduled and unscheduled maintenance. The preparation and transportation of all major items of equipment and hardware that have special requirements because of size, weight, shape, or environmental control, such as the total Tug vehicle, or major components such as engines, structures, computers, etc, are included.

Training functions include efforts necessary to provide training, and support for planning and conducting training programs for ground operations personnel to maintain manning levels required by the ground operations schedule. Provision of training equipment (models, trainers, audio visual aids, etc) is included.

Inventory control and warehousing management provides a centralized control for inventories and warehousing for all locations for materials, parts, supplies, tooling, equipment, spares provisioning in support of the operation of the Tug system. No analysts or programmers for computer control of inventory are included as that function may be included under fleet utilization.

Management of depot maintenance includes monitor and control of all factory and offsite maintenance and refurbishment such as major Tug components--engines, structures, avionics.

3.5.5.7 *Software Management* - Functionally this group provides for the maintenance and integration during the maintenance period of Tug, mission support, launch processing system (LPS) and other GSE software. GSE software integration includes interfacing with onboard and mission software and hardware to assure compatibility in a Tug avionics integration laboratory. Maintenance includes software configuration control and data development and input for specific mission and GSE applications. This function is primarily systems analysis and programming.

3.6 Safety Requirements and Support

Safety data relative to contingency situations that can impact Tug fleet utilization are provided in this section. The following paragraphs contain general information on safety policy and philosophy, definition of credible contingencies, and the requirements for safe backout.

3.6.1 General - The basic safety policy of the Space Shuttle program is to impose the minimum safety requirements on the Space Transportation System (STS) and its users to logically protect flight and ground personnel, STS elements and payloads, the general public, public/private property, and the ecology. Normal Tug ground operations include inherently hazardous operations that must be controlled and reduced to the lowest practical level consistent with program objectives, cost, and schedule. Deviations from the normal processing flow must be anticipated during Tug fleet operations.

Some of the deviations will have safety impact and require contingency planning. The Tug contingency safety philosophy must provide for backout to a safe condition or, as a minimum, to limit the extent of catastrophic events. The philosophy may be implemented by establishing adequate safety requirements for all credible

hazardous contingencies. The requirements would be expanded and refined as Tug designs and operational planning develops and lead to specific backout/emergency procedures.

3.6.2 Identified Contingencies - Analysis of the normal Tug ground operations flow, shown in subplan A, has identified potential contingency situations. The contingencies identified below are credible safety critical conditions that could impact fleet utilization.

3.6.2.1 *Main Propellant Leaks* - The loss of pressure integrity of the main propellant tanks may be identified during postlanding safing operations by vapor detection or leak checks. Leaks could develop during Tug propellant loading. Minor leaks are considered to be credible contingencies that should be accommodated. Major leaks (gushers) are highly improbable because of extensive qualification and acceptance testing.

3.6.2.2 *APS Propellant Leaks* - The detection of toxic, N_2H_4, vapor during postlanding payload bay ventilation would indicate a leak in the APS liquid system. Liquid leaks could develop during APS loading. Again, minor leaks are credible, but major leaks are not.

3.6.2.3 *Fuel Cell Leaks* - Fuel cell reactant system leaks may be identified during postlanding leak checks or during fuel cell loading.

3.6.2.4 *Handling Damage* - The accident/incident frequency during all transportation and handling operations indicates a high probability of the Tug sustaining damage requiring corrective action.

3.6.3 Safety Requirement - Specific procedures to backout from contingency situations must accommodate the varying severity of the hazardous conditions. Credible propellant leaks, for example, although defined as minor, could range upward from those barely detectable. Safety requirements, however, must address the assumed worst-case condition.

The basic safety requirements for contingencies, such as payload bay purging, ventilation, and personnel protection, have been adequately defined in Baseline Space Tug Requirements and Guidelines, MSFC 68M00039-1. The normal Tug processing safing requirements identified in subplan A, however, require changes that affect timelines and fleet utilization. These changes are summarized in the following paragraphs.

Leaks in the main propulsion system or fuel cell reactant system will require complete purging to an inert level before taking corrective action. In the postlanding phase, the purging must be done as soon as practical and before leaving the TPF airlock. In the event leaks develop during cryogenic loading, the commodities would be offloaded and purge established immediately. The Tug would then be removed from the Orbiter for corrective action.

Any detectable APS propellant leak during postlanding operations would require immediate venting of APS pressurant to reduce the leak. The liquid system would then be drained, flushed, and purged to an inert level as soon as possible. After corrective action has been verified by leak test, the system requires flushing, drying, and lockup with blanket pressure to return to normal operation. The same drain, flush, and purge operations are required to safe the system if a leak develops during APS loading.

The prevention of accidents/incidents during Tug handling is a function of adequate equipment, procedures, personnel training and certification, and constant surveillance. The extent of corrective action, should an accident/incident occur, is dependent upon the damage sustained. Any damage to fluid systems would require the safing actions defined in the preceding paragraphs.

The safety requirements imposed by contingency operations include those applicable to Tug, GSE and facility design, and definitive operations procedure detail. The Tug safety design requirements are included in the Tug Acquisition Phase Subplan (subplan F). The GSE and facility safety design requirements have been included in the Tug GSE Requirements Specification Data Sheets, contained in Appendix B, or the Tug Facility Requirement Specification Data Sheets, contained in Appendix C. The contingency operations identified are similar to current aerospace projects and the specific constraints are well known and accepted. These constraints are considered applicable to specific emergency procedures that will be developed during future Tug program phases.

3.7 Fleet Utilization and IUS/Tug-to-Payload Integration Requirements

Fleet utilization requirements are two-fold: (1) an identification of the resources required to operate the Tug portion of the STS, and (2) a definition of the management required of these resources. The resources include:

1) facilities, GSE and software requirements,

2) manpower requirements,

3) transportation requirements, and

4) IUS and Tug requirements.

Management of these resources includes functions discussed briefly here and in detail in Program Control System, Section 4.0 of this subplan. They include:

1) cost/performance management,

2) information management,

3) projection direction and configuration control,

4) fleet utilization planning and control,

5) logistics management,

6) software management,

7) systems engineering/integration.

IUS/Tug-to-payload integration requirements are discussed in subplan C of this report and the resources for integration are included. The management functions previously listed include IUS/Tug-to-payload integration, e.g., systems engineering/integration includes the payload integration as does fleet utilization planning and control.

3.7.1 <u>IUS/Tug Fleet Size Requirements Summary</u> - The IUS/Tug requirements are dependent on several factors: the traffic model, depicted in Table III-B-5; number of flights requiring expending a Tug; decision to make the IUS reusable or expendable, maximum number of flights a Tug (IUS) can make before it is "worn out," and the IUS/Tug transition and continuing use of IUS philosophy. Requirements can be further categorized--total fleet requirements, active fleet requirements, annual inventory requirements, etc.

The total fleet requirements (number of Tugs required and number of reusable IUSs required) are found using the basic formula in Figure III-B-15 which relates the quantity required to the number of flights, the number of expendable flights, maximum flights per Tug (IUS) and the number of flights by each expended Tug (IUS) plus unreliability losses.

The active fleet size requirements are a function of three factors: (1) Tug (or IUS) ground turnaround time, (2) annual launch rate, and (3) working days between launch centers. The inventory requirement combines the active fleet size requirements with the expendable Tug (or IUS) rate to indicate the number of Tugs (IUSs) in service in any one year. As the traffic model is better defined the inventory requirement can be determined on a shorter basis (monthly) to better allocate facility storage space.

Table III-B-5 Traffic Model for Tug and IUS

Year / Configuration	No. of Flights 80	81	82	83	84	85	86	87	88	89	90	91	Total
Expendable IUS (No Transition)	9	16	14	17									56
Expendable IUS (1-yr Transition)	9	16	14	17	7								63
Expendable IUS (Continuing)	9	16	14	17	7	4	3	1	1	2	1	1	76
Reusable IUS (No Transition)	10	20	14	16									60
Reusable IUS (1-yr Transition)	10	20	14	16	8								68
Reusable IUS (Continuing)	10	20	14	16	8	5	4	2	2	2	2	2	87
Tug-No Transition with IUS					19	22	24	18	18	16	26	22	165
Tug-1-yr Transition with IUS					13	22	24	18	18	16	26	22	159
Tug-Continuing use of IUS					13	19	23	18	18	16	26	22	155
Expendable Flights	2	7	2	3	2	2/4	1/2	1/0	0/0	1/0	0/1	1/1	22/8
(Included in totals)	Reusable IUS					IUS/Tug							

Note: 1. 1980 IUS data from Martin Marietta Study for SAMSO
2. All reusable IUS data from Martin Marietta Study for SAMSO and derived from MSFC-supplied expendable data for 1984 and beyond
3. All Tug data from MDAC and MSFC (for Transition and Continuing IUS use)
4. Expendable IUS data for 1981 through 1983 from MDAC

$$\text{Total Tugs Required} = \text{Total Number of Expendable Tug Flights} + \left[\frac{\text{Total Number of All Tug Flights} - \text{Total Number of Flights by Tugs Being Expended}}{\text{Maximum Number of Flights per Tug}}\right] + \text{Unreliability Losses}$$

Note: The formula is the same for Reusable IUS, Substitute IUS, and IUS data.

Figure III-B-15
Basic Formula for Determining Numbers of Tugs and IUSs Required

3.7.1.1 IUS Fleet Size Requirements - The IUS requirements are dependent on a basic program decision yet to be made, that is, will the IUS be expendable or reusable? For that reason, the IUS requirements for both configurations will be listed. Another big variable in the IUS requirements is the basic decision of transition between Tug and IUS in 1984 and the number of residual IUS flights after 1984. The following paragraphs define the IUS requirements for the indicated condition.

Expendable IUS Fleet Size Requirement - No Transition with Tug - The total IUS requirement in this case is simply the sum of the flights indicated in Table III-B-5 as 1 flight = 1 IUS for a total of 56. The active fleet and annual inventory in this case are synonymous and are equal to the annual launch rate for the years 1980 through 1983, as listed in Table III-B-5.

Expendable IUS Fleet Size Requirements - 1 Year Transition with Tug - The total IUS requirements are the sum of the flights, again from Table III-B-5, a total of 63. The active and annual inventories, similarly, are the annual launch rates for 1980 through 1984.

Expendable IUS Fleet Size Requirements - Continuing IUS Use through 1991 - Once again referring to Table III-B-5, the number of IUSs required is 76 and the annual launch rate is the active fleet or annual inventory.

Reusable IUS Fleet Size Requirements - No Transition with Tug - Using the number of flights and the number of expendable flights from Table III-B-5 and putting those into the formula of Figure III-B-15, gives a total of 15 to 18 IUSs to satisfy the flight schedule (assuming maximum of 20 flights per IUS). The active fleet size requirement is one for each year except 1981 which has a requirement of two, as shown in Figure III-B-16 based on annual launch rate. Figure III-B-17 depicts the annual IUS inventory requirements based on launch rate and expendable flight requirements. The requirements for 1984 and beyond in the figure should be ignored.

Reusable IUS Fleet Size Requirements - 1 Year Transition with Tug - The traffic model and quantity formula in this case combine to yield a total IUS requirement of 17 to 20 in the total fleet. The active fleet is one for each of the years 1980, 1982, 1983, and 1984 and two for 1981. Figure III-B-17 reflects the annual inventory requirements for 1980 to 1984 based on launch rate and expendable flights.

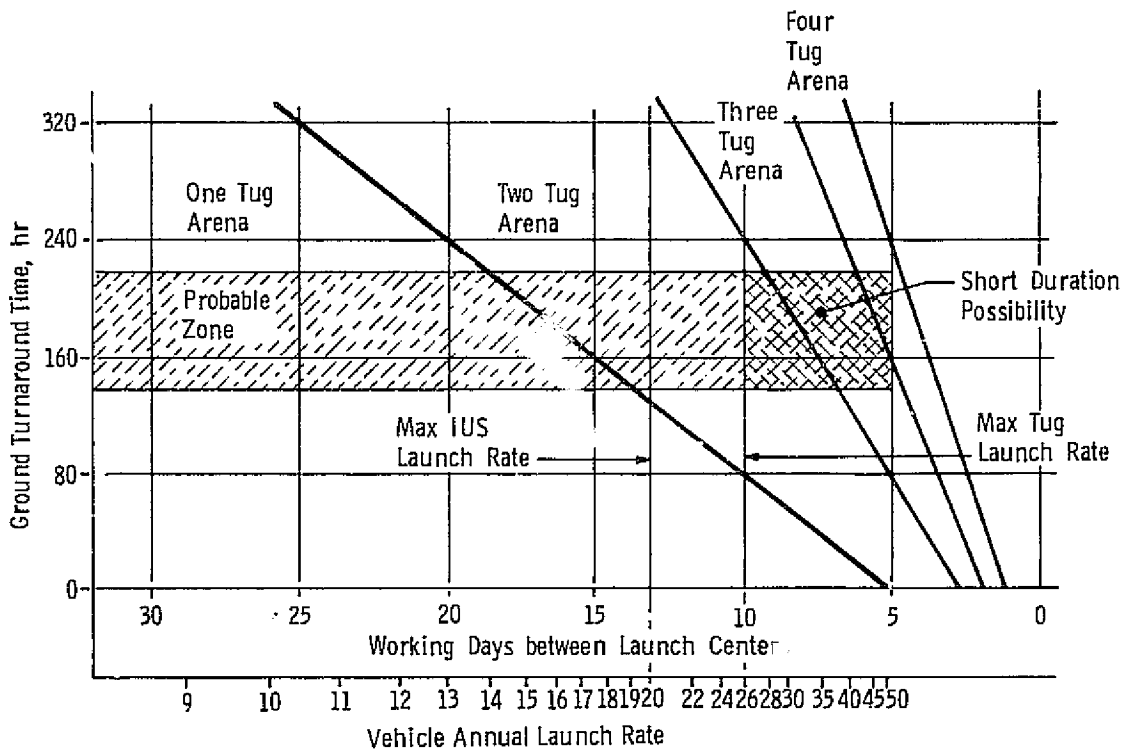


Figure III-B-16
Vehicle Active Fleet Size - Tug or IUS - vs Turnaround Time, Launch Rate, Launch Cente s

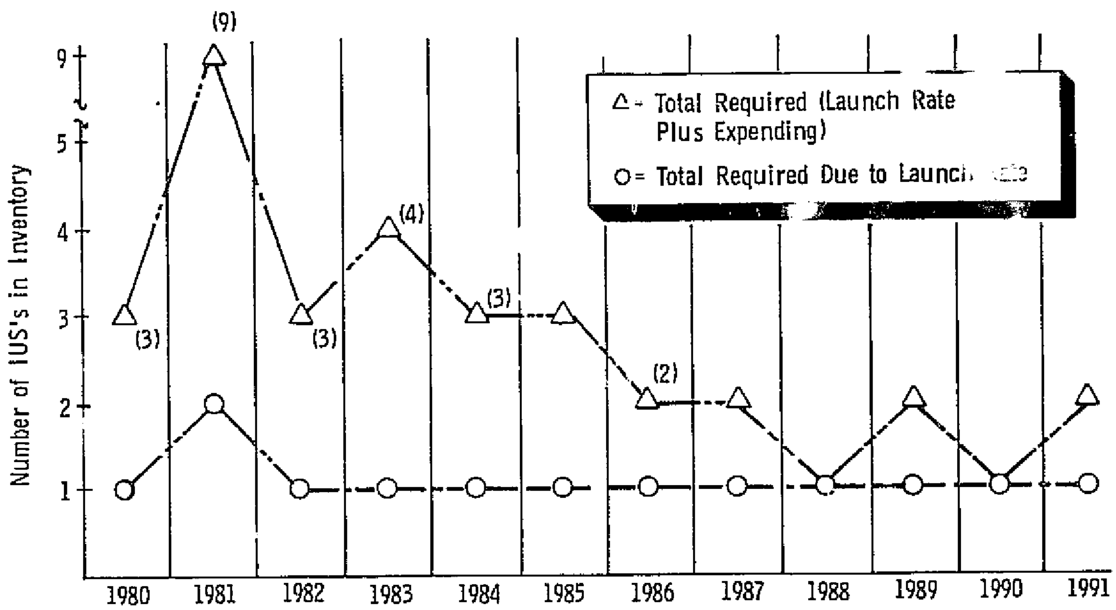


Figure III-B-17
Minimum Annual Reusable IUS Inventory Requirements

Reusable IUS Requirements - Continuing IUS Use through 1991 - Again the same figures yield a total IUS requirement of 23 to 27, one in the active fleet for every year except 1981 and annual inventory, as shown in Figure III-B-17 for each year 1980 through 1991.

3.7.1.2 *Tug Fleet Size Requirements* - The Tug requirements for the total program will vary between 13 and 16 using the flight model of Table III-B-5, the formula of Figure III-B-15, and 20 as the maximum number of flights per Tug ("Wear Out"). The range is reduced by one (13 to 15) if the IUS is retained through 1991. The big variable to be reckoned with is the number of flights each of the expendable Tugs makes before it is expended.

The active fleet size requirements for each year 1984 through 1991 is two based on annual launch rate, except for one year, 1989, which has a requirement for only one Tug - as Figure III-B-16 attests.

The annual Tug inventory requirements, as shown in Figure III-B-18, are based on the active fleet size requirements plus expendable Tug requirements. In addition to the quantities shown in the figure, it is recommended that a backup Tug be added (to support contingencies) to the active fleet size for all years except 1984 (1984 requires no additional backup as those provided in that year for expendable Tug flights will not be expended in 1984, but in 1985). The backup Tugs do not affect total quantity requirements, only on-dock delivery date requirements.

3.7.1.3 *Kick Stage Requirements* - The kick stage requirements are identified in Figure III-B-19 for the various configurations of IUS and the two time periods of IUS past 1983 (1 year transition and residual IUS usage through 1991). The requirements have not been summed in the figure because of the various possible combinations. That summing follows:

1) Expendable IUS-No Transition (1980-1983)

    6 Kick Stages (14K)
    6 Kick Stages (5K)

2) Expendable IUS-1 year Transition (1980-1984)

    8 Kick Stages (14K)
    7 Kick Stages (5K)

3) Expendable IUS-Residual IUS through 1991 (1980-1991)

    10 Kick Stages (14K)
    11 Kick Stages (5K)

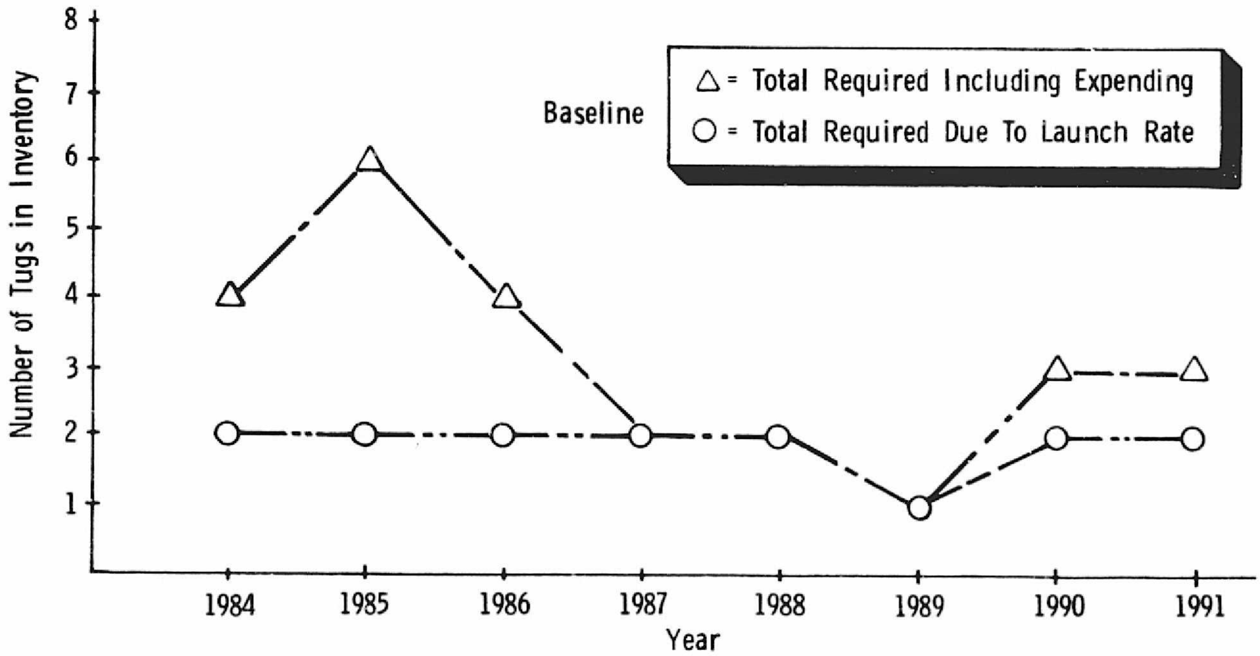


Figure III-B-18 Minimum Annual Tug Inventory Requirements

▲ IUS Kick Stage Requirements	MMC Data	MDAC Data			MMC Data* (IUS & Derived Data)							
Configuration / Year	80	81	82	83	84	85	86	87	88	89	90	91
Expendable IUS												
Single KS		2-14K		2-5K			1-5K					
Dual KS 14K&5K	1	3			2	1		1				
Reusable IUS												
Single KS-5K	7	12	11	13	6	3	2	2	1	1	1	1
Dual KS 14K & 5K	1	6			1	1	1		1		1	
▲ Tug Kickstage Requirements (MDAC Data)												
Single KS					4-5K		1-5K	2-5K	1-14K			1-5K

*Based on: 1) 80% of All Reusable IUS Flights Require KS and 80% of Those Use A Single 5K KS
2) 16% of All Expendable IUS Flights Require KS and 75% of Those Use A Dual (5K & 14K) KS

Figure III-B-19 Kick Stage Requirements

4) Reusable IUS-No Transition (1980-1983)

   7 Kick Stages (14K)
   50 Kick Stages (5K)

5) Reusable IUS-1 year Transition (1980-1984)

   8 Kick Stages (14K)
   57 Kick Stages (5K)

6) Reusable IUS-Residual IUS through 1991 (1980-1991)

   12 Kick Stages (14K)
   72 Kick Stages (5K)

7) Tug Requirements (1984-1991)

   5 Kick Stages (14K)
   4 Kick Stages (5K)

3.8 Site Activation and Verification

Not applicable to this subplan.

3.9 Ground Software Development (Contingencies)

The development of the ground software from IUS-to-Tug transition phase, site activation phase through the Tug operational phase is generally covered in other subplans of this report. In this subplan, the primary emphasis is on problem areas in an established STS and associated ground software systems.

The primary problem areas are late delivery of software and software failures, both in real time. For late delivery of software, two courses of action are available: (1) late delivery during this phase will probably be at the software module or subroutine level based on changes to the system; therefore the module can be bypassed temporarily while more programmers are assigned to the specific task and the changes verified in a simulation laboratory; (2) at the software module level the change may be made and validated onsite using the actual flight Tug hardware or a high fidelity mockup. The action taken will depend upon the extent of the change to both the software and the hardware. For late delivery of new software modules, onsite make up and validation is not recommended.

Software failures at the module level, like late delivery, may be corrected and validated onsite using the actual flight hardware or a high fidelity mockup. Failures may be negated by redundant software modules.

Late deliveries and failures involving major protions above the module level, of the software system, may require launch rescheduling as the only alternative, while the problem is resolved in a simulation laboratory.

3.10 Logistics/Maintenance

Logistics/maintenance are discussed in detail in Section 4.0 Program Control System, of this subplan. A summary is presented here to lend continuity to this subplan.

Logistics management for Tug must provide direction and control of the interfacing elements of the logistics function during the life of the project, including preparation and maintenance of a Tug Integrated Logistics Support Plan; development and refinement of the Support Requirements Analysis; coordination of logistics requirements between NASA, the Tug contractor, and various suppliers; development of logistics milestones and scheduling of activities; and effective planning and implementation of resources. All of those are of new importance because of the concept of refurbishment and reuse of the Tug.

The Logistics Support Requirements Analysis (SRA) is the initial and most important management tool needed to assess the interfacing impact of system and phase logistic elements and to avoid down-stream problems through early identification of requirements in the definition and design phase. A SRA establishes criteria for design and provides the data necessary to control those aspects of design and development that reduce support costs.

3.10.1 Maintenance and Refurbishment Planning and Control - The maintenance/refurbish element of logistics management will be responsible for planning, major scheduling, and control of all Tug maintenance and repair activity. The Tug contractor's Maintenance Engineering Analysis will establish early planning factors. Levels and location of maintenance, reparable/nonreparable status, repair locations, and necessary supply categories will be established. The basic maintenance concepts of remove and replace to the LRU level will generally be followed. Level I, II, and III maintenance concepts will be provided.

A Tug Program Operational Maintenance/Refurbishment Plan should be provided for all maintenance activity to include Tug maintenance approach, maintenance tasks by subsystem and component, task sequences and flow personnel skill levels, and resources necessary to the maintenance function. A Tug Postflight Maintenance Activity Plan should be provided to include provisions for fleet and individual Tug maintenance status reporting, maintenance planning update and revision, spares provisioning and reorder, and reassessment/assignment of maintenance task times.

3.10.2 Spares Acquisition and Management - Spares acquisition and management will be based on delayed procurement of spares for high probability of design change items, anticipated high cost items, and the desired experience factor in new technology area items where production cycles permit. If delayed procurement is not feasible, a decision should be made for concurrent buy of both production parts and spares to achieve quantity buy price break.

Based on the decision of the selection process, spares will be provisioned for KSC Level I and II activities and for Depot operations (Level III). Warehousing and inventory control management of spares will be established and maintained to support test and maintenance activities at KSC and WTR. The initial stock of spares, primarily LRU items, will be resupplied and resized on the basis of verified usage through mechanized system. Configuration control of spares will be maintained through the engineering change control system.

Operations and Maintenance Manuals (O&M Manuals) will be provided for the overall Tug and for each subsystem as well as for contractor furnished GSE. Tug O&M Manuals will cover functional description; theory of operation; system interface requirements; maintenance procedure including trouble analysis and malfunction isolation, servicing, removal and installation; alignment and adjustment; necessary diagrams and schematics; handling, packaging, preservation, and storage requirements; and parts and components listing including spares and limited life components. GSE manuals will contain detailed operational and maintenance instructions and will include equipment description, operation, failure analysis and fault isolation, servicing, alignment, adjustment, cleaning, repair, test and inspection, and overhaul instructions.

3.10.3 Tug Training - Training will be provided for fleet management personnel who will require both planning and operational phase instruction on the Tug itself and the varied aspects of its management support, and ground crews to handle, checkout, maintain, and service the Tug. Air Force personnel will require Tug training to support their operational program during IUS/Tug transition and Tug operational phases.

Cost effectiveness demands that maximum use be made of the Tug contractor's training program to satisfy NASA and Air Force requirements, and courses developed for contractor training should be formatted to also satisfy NASA/Air Force requirements.

Video tape development by the contractor at familiarization or skills levels on systems not subject to a high degree of design change proved cost effective on Skylab and should be considered.

3.10.4 Transportation and Handling - Transportation and handling is treated in section 4.0 of this subplan.

3.11 Configuration Management

Configuration Management requirements are discussed in detail in section 4.0 and summarized here to lend continuity. Configuration Management is a function that is required throughout the life of the Tug program and is therefore a vital element of Fleet Utilization management during the operational phase of the program.

Configuration management provides the necessary procedures and disciplines to achieve effective control over the hardware, software, and operational activities of the Tug program. This control is needed on a continuing basis throughout the life of the program. The objective of Configuration Management is to ensure the maximum operational capability through formal initial definition of configuration, controlled approval of changes, and continuing and accurate recording of the exact configuration of systems and selected equipment.

3.11.1 Configuration Definition - All requirements imposed on the configuration will be manifest in documents under control of configuration management. During the DDT&E phase, this document for the Tug system will be developed to define a configuration baseline to be used for control and accounting of future changes. Such documentation and management will recognize the interface and requirements imposed by the several NASA agencies and the DOD.

The documents to be managed (maintained) during the Fleet Utilization phase includes:

1) NASA Level II Documents - Plans, Requirements;

2) Specifications - Defines Technical Requirements;

3) Interface Control Documents (ICD) - Design Control between Agencies, including DOD;

4) Operational Plans - Control Activities, Tasks, and Resources;

5) Drawings - Defines Configuration.

3.11.2 Change Control - Change control is a systematic evaluation, coordination, disposition and implementation of all approved changes in a configuration after formal establishment of the configuration definition. After a baseline is established, positive control will be established to preclude unauthroized changes to that baseline.

3.11.2.1 Change Management - Control of Tug requirements and changes thereto will be provided through the use of Configuration Control Boards (CCB) and the applicable baseline documentation by both NASA and DOD. Figure III-B-20 illustrates the CCB organization. Note that the NASA and the DOD are always represented on every CCB.

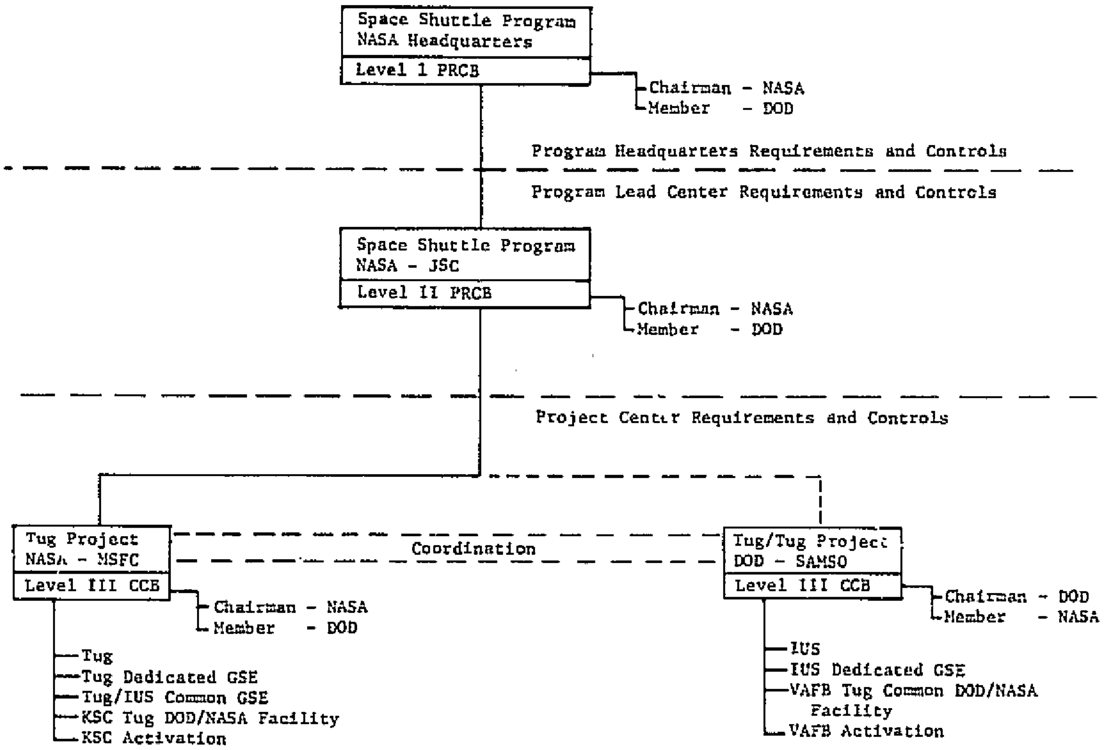


Figure III-B-20 Configuration Control Board Levels

CCB activities will include all functions associated with change management such as interrelationship with other CCBs, change submission, disposition and change closeout.

3.11.3 Fleet Utilization Configuration Management - During this phase of the program, changes will be under the cognizance of Fleet Utilization management of the Tug system. It is expected that the bulk of the activity will be minor configuration changes; however, a block build concept in the system could cause major perturbations and require substantial CCB activity.

3.12 Timeline Funding

Not Applicable. See Volume IIIof this report, Program Study Cost Estimates.

4.0 Program Control Systems

Fleet management for the Tug ground and flight operations program should provide a diverse set of services. These services include performance management, configuration management, data management, quality assurance and safety, sustaining engineering, logistics, interface control, mission planning, flight planning, and Tug fleet utilization planning. To provide effective fleet management visibility and control, adequate program control systems must be implemented. The man/machine relationship illustrated in Figure III-B-21 is the approach used where the computer can most effectively generate data needed for decisions. Concepts for selected systems and techniques recommended are described in this addendum. The basis for recommending each system is discussed in this section.

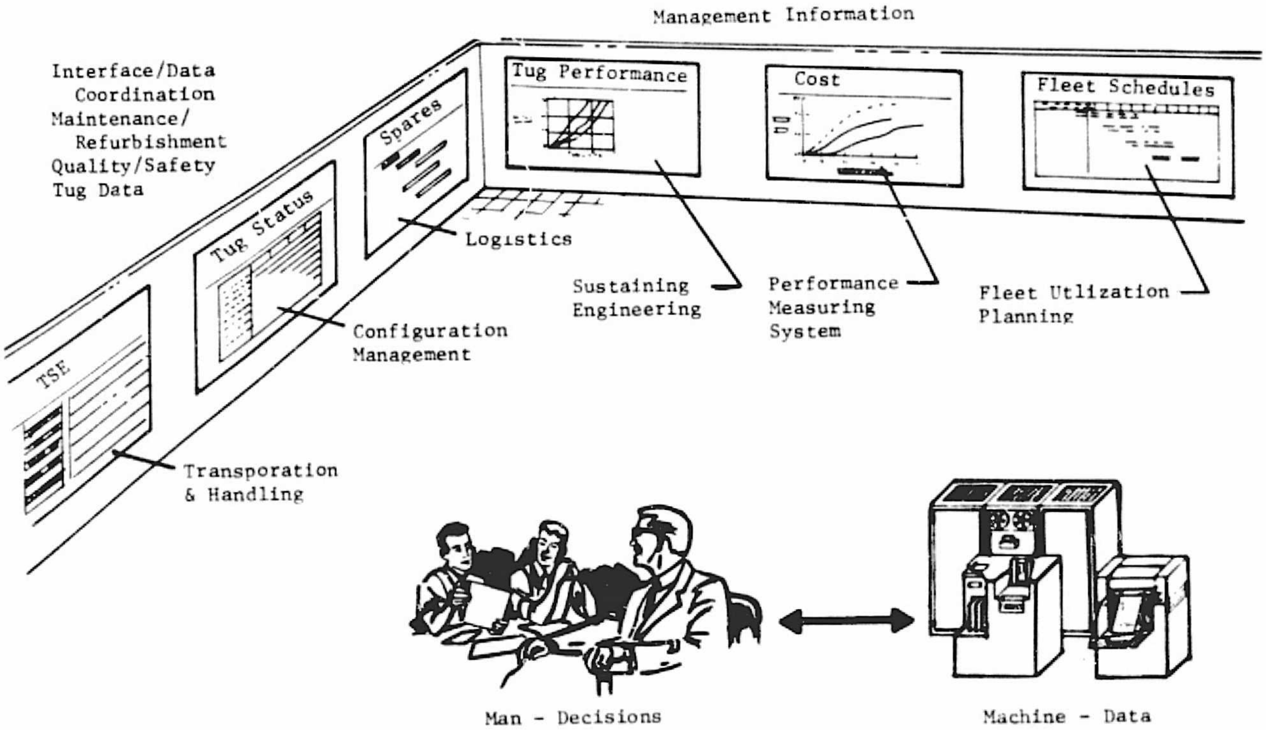


Figure III-B-21 Fleet Management

The Performance Management System includes planning and work authorization, cost per flight, and a Performance Measuring System (PMS). This system is adapted from that currently in operation at Martin Marietta Corporation's Orlando Division, and has been demonstrated and is being implemented on the External Tank project after extensive evaluation of various PMSs. For the latter system, the key performance parameter is cost per flight for a large number of tanks, which is analogous to cost per flight for a large number of Tug launches. The major differences between the two systems are elimination of the design-to-cost parameter, which is a decisive part of the cost per flight for tank production, and establishment of work packages at a generally higher level of the Work Breakdown Structure (WBS) because of the relatively low cost per launch for the ground operations WBS elements.

A machine assisted Tug Fleet Utilization System is a management tool necessitated by the high rate of missions that must be accommodated by the Tug fleet over an extended period of time. The drivers for determining the optimum location for this system are the requirements for continuous project management involvement for many sustaining engineering skills, and close coordination with the Shuttle project management.

The Configuration Management System driver is provision for a comprehensive review of all baselines and changes by all cognizant parties. The basic system is a conventional implementation of MSFC Document MM8040.12, Standard Contractor Configuration Management Requirements, which has been proven to be effective. The challenge is to provide for a timely review and approval cycle.

The Information Management System (IMS) includes both data management and the Management Information Center (MIC). The dominant consideration is establishing adequate compatibility of this system with other Space Transportation System IMSs. For data management, this can be accomplished by establishing a system that is compatible with the Space Shuttle program information control and retrieval system in terms of equipment and software for mechanized information submittal schedules and status, and information accessioning lists. The Management Information Centers should be planned on an austere basis to be cost effective. Compatible data and communications equipment are needed. Real time data can be limited to that required for the Fleet Utilization System.

Development of Logistics Operations planning as well as extensive technical documentation and training programs must be accomplished in collaboration with the Tug project prime contractors and their suppliers. Centralized spares provisioning and control are required to be cost effective because of the large number of spare line replaceable units, the verying reorder lead times, and the complexity of maintaining all status data (including shelf life,

life cycle data, configuration status, etc). Control of the logistics systems and techniques, as defined, can best be accomplished at a location that facilitates the project management, design and sustaining engineering, and configuration control support. The traditional transportation planning and coordination role of the project office is applicable.

4.1 Performance Management System

The recommended Performance Management System is a man/machine system that integrates planning, scheduling, budgeting, work authorization schedule status, and the cost accumulation system to provide management with planned versus actual cost, schedule and cost per flight visibility. The principal elements of the performance management process and their relationships are shown in Figure III-B-22 which shows the work and information flow between the three main components - planning and work authorization, performance measurement, and cost per flight.

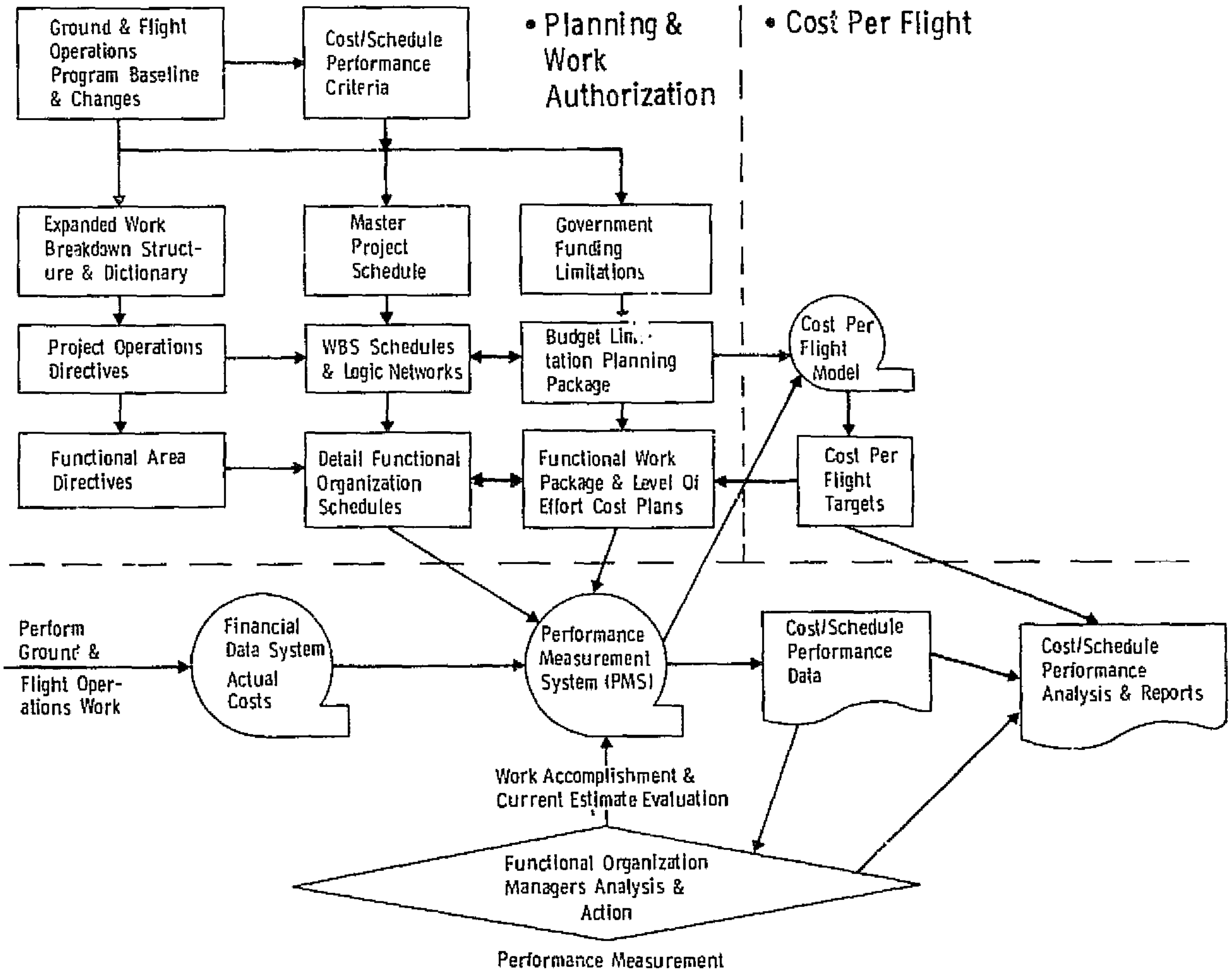


Figure III-B-22 Performance Management System

4.1.1 Planning and Work Authorization - Planning and work authorization is performed by man. Project level direction and an expanded Work Breakdown Structure (WBS) and WBS dictionary are derived from the program baseline and changes. Project directives should define work requirements for the total program in accordance with the Work Breakdown Structure (WBS), assign responsibilities, and should be the basis for lower tier functional element directives. Cost and schedule performance requirements are extracted from the program baseline and changes, and provide the basis for issuing master project schedules and government funding limitations. From these data, WBS schedules and logic networks with an associated budget limitation planning package can be developed to an appropriate WBS level, and issued by project management. Logic networks are those used in the Tug Fleet Utilization Planning System and the WBS schedules are manually prepared by augmenting schedules from this system with level of effort schedule data. Appropriate mechanized cost per flight model input is made. These data are the basis for functional organization management to develop and issue detail schedules, work packages, and level of effort work plans that are input to the mechanized Performance Measurement System (PMS) as time oriented cost data. Trend analysis should be used to improve work package cost and schedule planning.

4.1.2 Performance Measurement - Performance measurement is accomplished by the PMS by using the input previously described and actual cost data obtained from the financial data system to provide time-related cost performance data and revised cost input to the cost per flight model. These data and schedule status data obtained from status meetings and the mechanized Tug Fleet Utilization Planning System should be analyzed by the functional organization managers and a work accomplishment and current estimate evaluation made. Input from this evaluation should be used to revise the temporal cost performance reports, if necessary. The iterated cost and schedule performance data can then be used to prepare the monthly data and reports, including the integrated monthly cost and schedule analysis.

4.1.3 Cost Per Flight - A cost per flight target tracking system should be used to apply pressure and facilitate management decisions required to meet this parameter. The objective is to instill cost awareness in each member of the team so that he is searching for ways to reduce cost as an every day mode of operation. Cost per flight targets can be developed using improvement curve data and can be revised as a result of trend analysis and baseline changes.

4.1.4 Work Packages - Performance measurement should be keyed to WBS work packages containing input and output requirements identified to the project functional flow logic diagram with start and stop dates tied to the most detailed project schedules and budgets. The criterion for WBS work packages is that they contain measurable units of work that are a part of the normal ground operations program instead of arbitrary dollars and time limits. Each work package should be a specific job that has:

1) an end result,

2) a budget,

3) a short time span,

4) a schedule, and

5) a charge number.

This enhances management visibility and allows a more quantitative assessment of task accomplishment than would be possible if parameters were not readily identifiable with the task.

Figure III-B-23 illustrates the way that work packages should be developed from the WBS, and shows that a functional cost account is identified for each class of cost and functional element of the organization. The WBS level from which the work packages are generated is established by the list of requirements.

4.1.4.1 Performance Event Factor Work Package - Performance event factor work packages should be used for tasks such as test and maintenance where a large number of events are planned. Earned value work sheets continuing the previous month status are provided from the computer for use by the responsible analyst. Work package percent complete is based upon performance events completed as a ratio to total work package events scheduled.

4.1.4.2 Procurement Work Package - Procurement work packages can be used for purchased parts, assemblies and lots of materials (such as propellants). The budgeted cost of work performed can be derived from the inventory system using budgeted values upon withdrawal from inventory. This is compared to the work package total budget to calculate percent complete.

4.1.4.3 Assembly Work Packages - Assembly work packages may be used for selected maintenance tasks if improvement curve oriented standard hours can be developed for each maintenance step in the task. Percent complete is the ratio of the standard hours for the steps completed to the standard hours for the complete task.

C-3

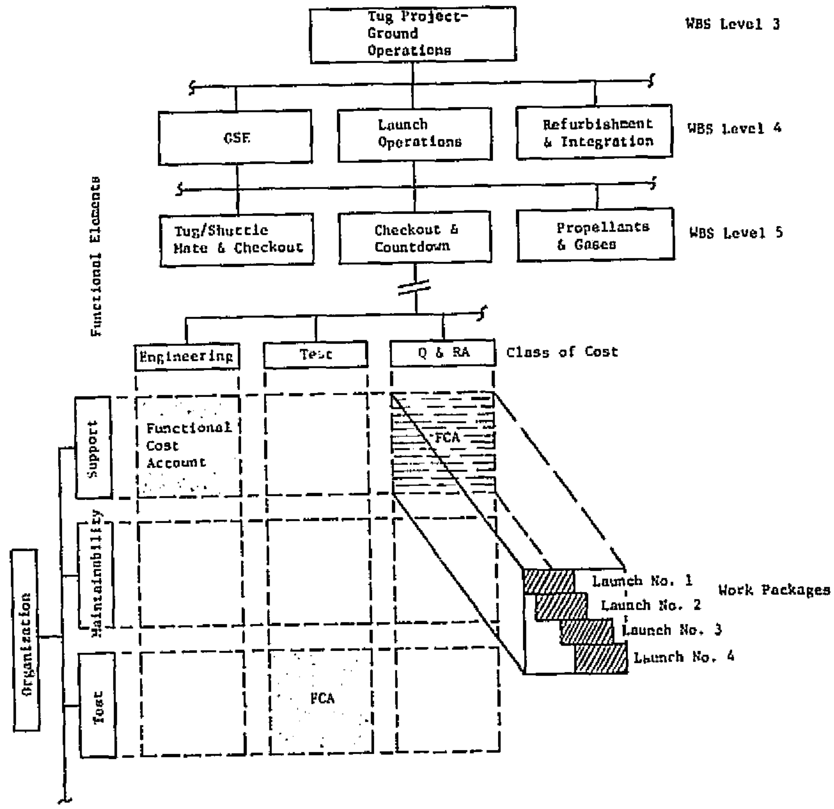


Figure III-B-23 Typical WBS/Work Package Relationship

4.1.5 Time Oriented Effort - Time oriented effort is a level of effort package that has:

1) no end product,

2) no specific schedule,

3) no discretely defined work, and

4) a charge number.

This type of package should only be used for effort that cannot be divided into discrete work packages. There is no percent complete discriminator because budgeted cost of work performed is equal to budgeted cost of work scheduled. These packages are identified in the WBS at a less detailed level than work packages. The effectiveness of the Performance Measurement System is enhanced by minimizing the work that must be controlled by time oriented effort.

4.1.6 Planning and Baseline Control - Rolling wave planning provides the means to readily maintain a disciplined performance baseline without obscuring problems, and yet remain responsive to change requirements. By this system planning, packages are scheduled and

budgeted for the entire program and are expanded into detail work packages progressively. Work packages authorized to start during the next half year period are defined and planned in detail by the functional organizations three months before the start of that period. This approach allows detail monitoring, control and analysis of near-term work, and at the same time provides for an easy response to implementing changes in program requirements, funding limitations, and changes resulting from trend analysis.

4.1.7 Management Reserves - Before issuing budgets a management reserve to protect funding and cost commitments at completion should be established by project management. Schedule time should also be reserved to protect important project milestones.

4.1.8 Performance Measurement System (PMS) - The computerized PMS that is recommended has the features needed for the ground operations Performance Management System. It accumulates, stores, and maintains the performance history of completed work, and validates new work package plans within the planning package allowable budget and schedule. A feature of this PMS is the discrete identification of each change to each planning and work package. These transactions should be incorporated within 30 days and reported monthly. A complete contract history file is maintained.

The PMS consists of a logic network module and a program data module. It obtains actual cost data from the Financial Data System for report generation.

4.1.8.1 Budgeted Cost of Work Scheduled (BCWS) - The tabulated output of the PMS includes temporal BCWS and actual cost data that are readily charted as shown in Figure III-B-24. Budget variance at any time is the dollar difference between the time versus dollars plot of the BCWS and actual cost experienced. Because the budgeted cost of work performed is equal to the BCWS for level of effort packages, the budget and cost variances are equal. This is rarely true for work packages.

4.1.8.2 Budgeted Cost of Work Performed (BCWP) - The tabulated output of the PMS also includes temporal BCWP data for work packages and Latest Revised Estimate (LRE) data for work and level of effort packages. Figure III-B-25 shows these data added to the type of data shown in Figure III-B-24. For work packages, cost variance is the dollar difference between the temporal plot of the BCWP and actual cost, and the budgeted dollar value of the schedule variance is the difference between the BCWP and BCWS. For work and level of effort packages, the estimated cost and schedule variance at completion can be determined from the total BCWS and total LRE coordinates. At completion the BCWS and BCWP are equal for work packages.

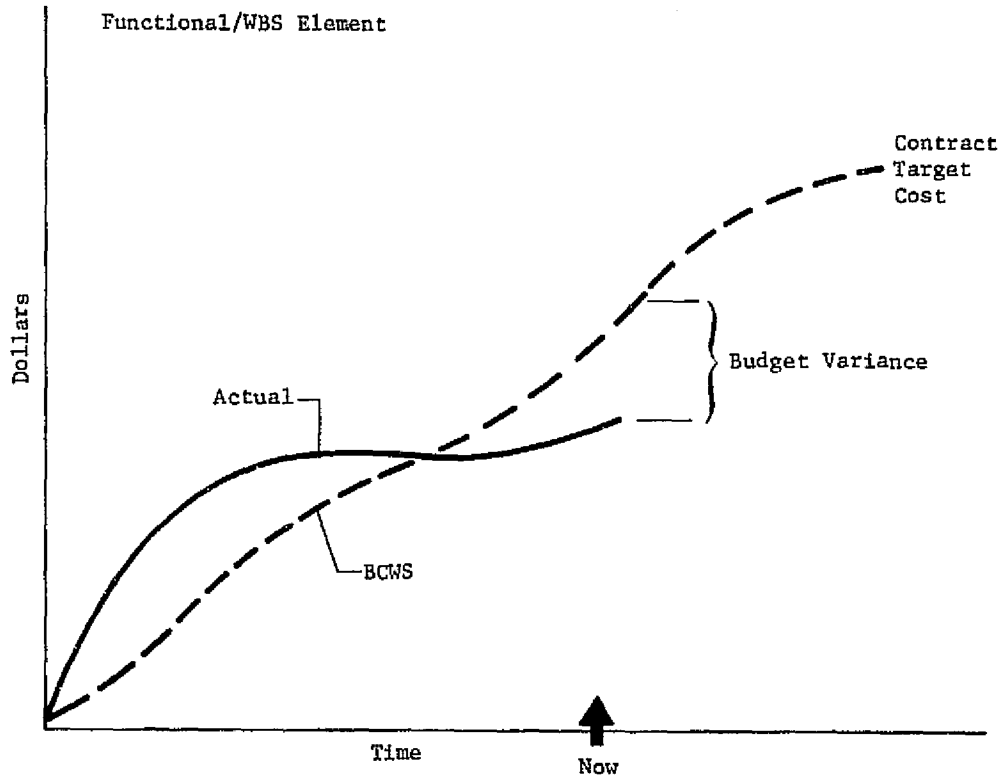
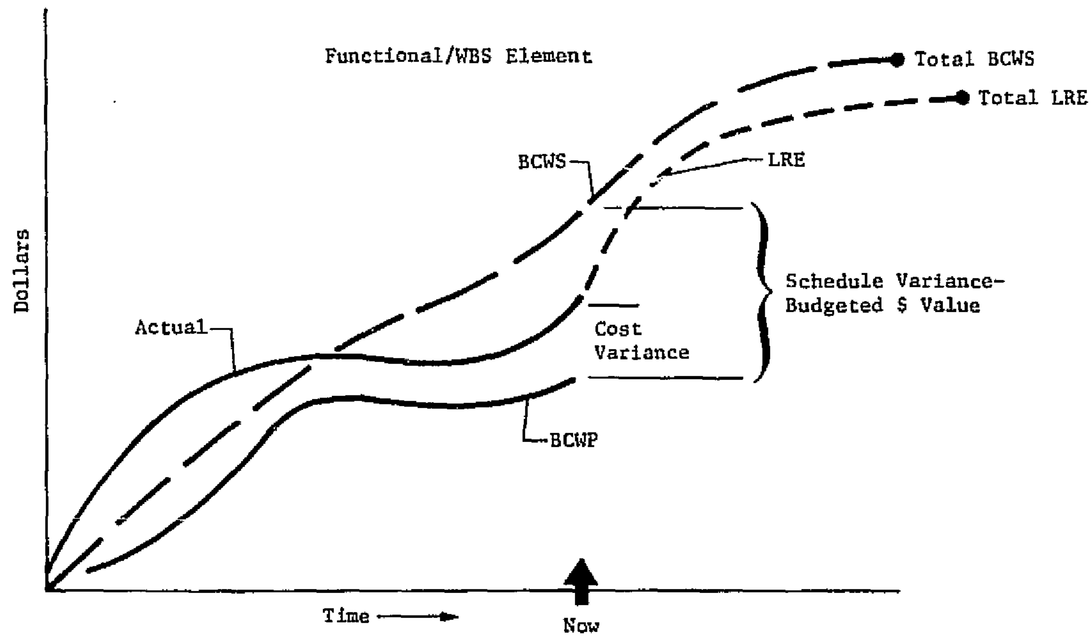


Figure III-B-24 Budgeted Cost of Work Scheduled (BCWS)



Comparison of BCWP to BCWS Reflects Schedule Variance
Comparison of BCWP to Applied Direct Cost Reflects Cost Variance
Comparison at Completion of LRE and BCWS Reflects Both Estimated Cost and Schedule Variance at Completion

Figure III-B-25 Budgeted Cost of Work Performed (BCWP)

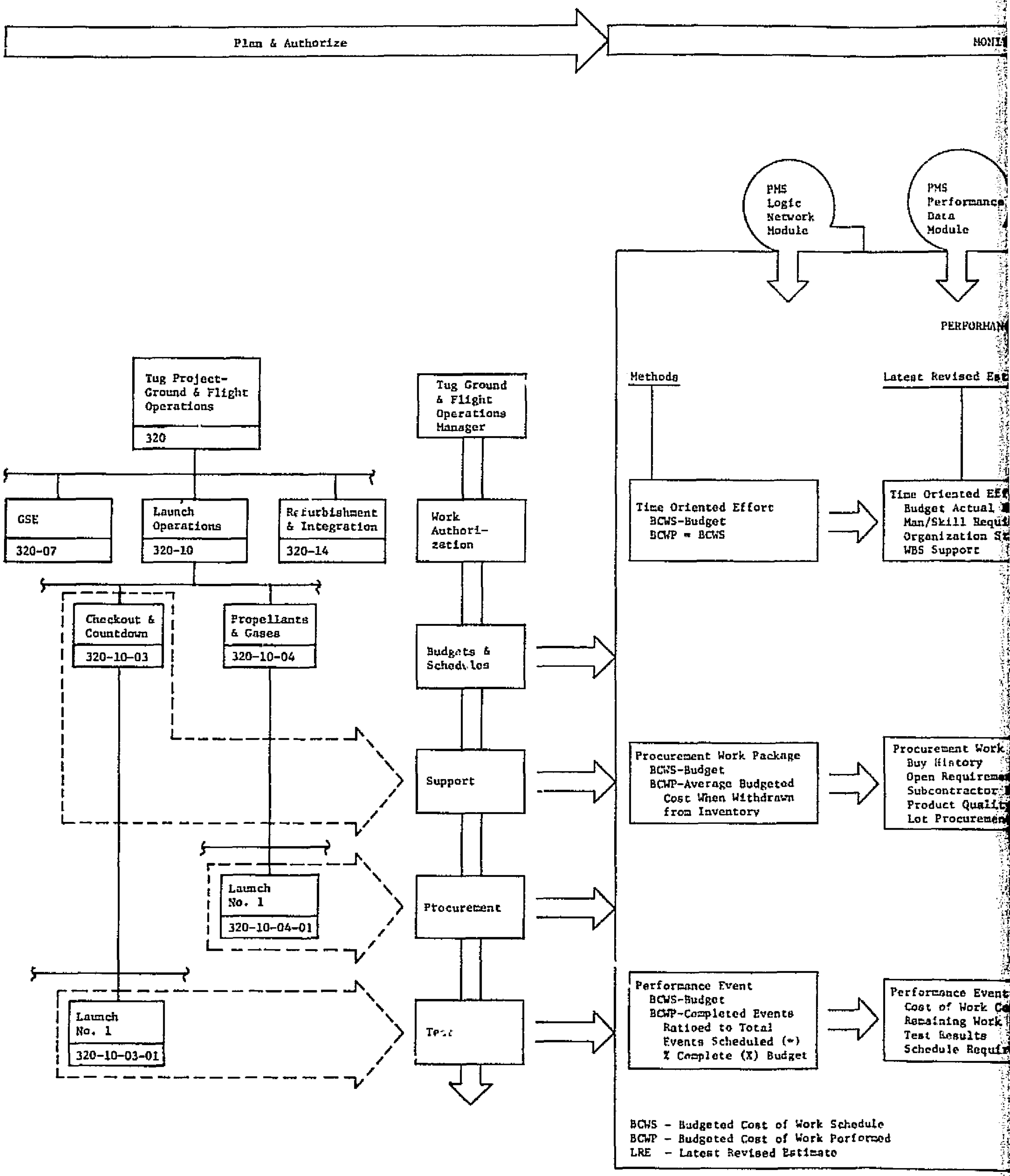
4.1.9 Performance Status and Assessment - The primary objective of the Performance Management System is to assemble correlated cost, schedule, and cost per flight data to assist management in the timely identification of problems, and to support corrective actions. Our recommended PMS will provide both functional organization and higher level management with summary and detail level cost tracking reports and diagnostic data keyed to the WBS. Correlated schedule data can be obtained from the Tug Fleet Utilization Planning System described in Section 4.3.2. The operation of the Performance Management System will be discussed in terms of the three major performance status and assessment elements illustrated on Figure III-B-26.

4.1.9.1 Plan and Authorize - Project operations directives should be issued and maintained to define the work requirements in terms of the Work Breakdown Structure (WBS) and dictionary, the master schedules, and the government funding limitations.

The Tug project ground and flight operations is at WBS level three. Lower level cost and schedule planning and control starts with level four of the WBS and proceeds through the work package detail planning level. The WBS level at which a given degree of detail occurs is dependent on the level of the elements being analyzed; launch operations serves as an example.

For launch operations, the project should issue and maintain the logic network and schedules at WBS level five from mechanized Tug Fleet Utilization Planning System data supplemented by manually developed schedule data for level of effort activities. The associated budget limitation planning package should also be issued and maintained. This level of detail is adequate because resource limitations are not too large and well defined work package detail can be developed at the next lower level. Cost and schedule planning data must be developed at each higher WBS level so that project data can be summarized at successively higher levels for management visibility and control.

Functional areas should plan and authorize work packages, when the output can be specifically measured, and time oriented effort packages for the remaining work. For this example, work packages can be readily developed and measured for each launch by extending the WBS to level six. However, supporting time oriented effort should be planned at level five because it is not allocated by specific launches.



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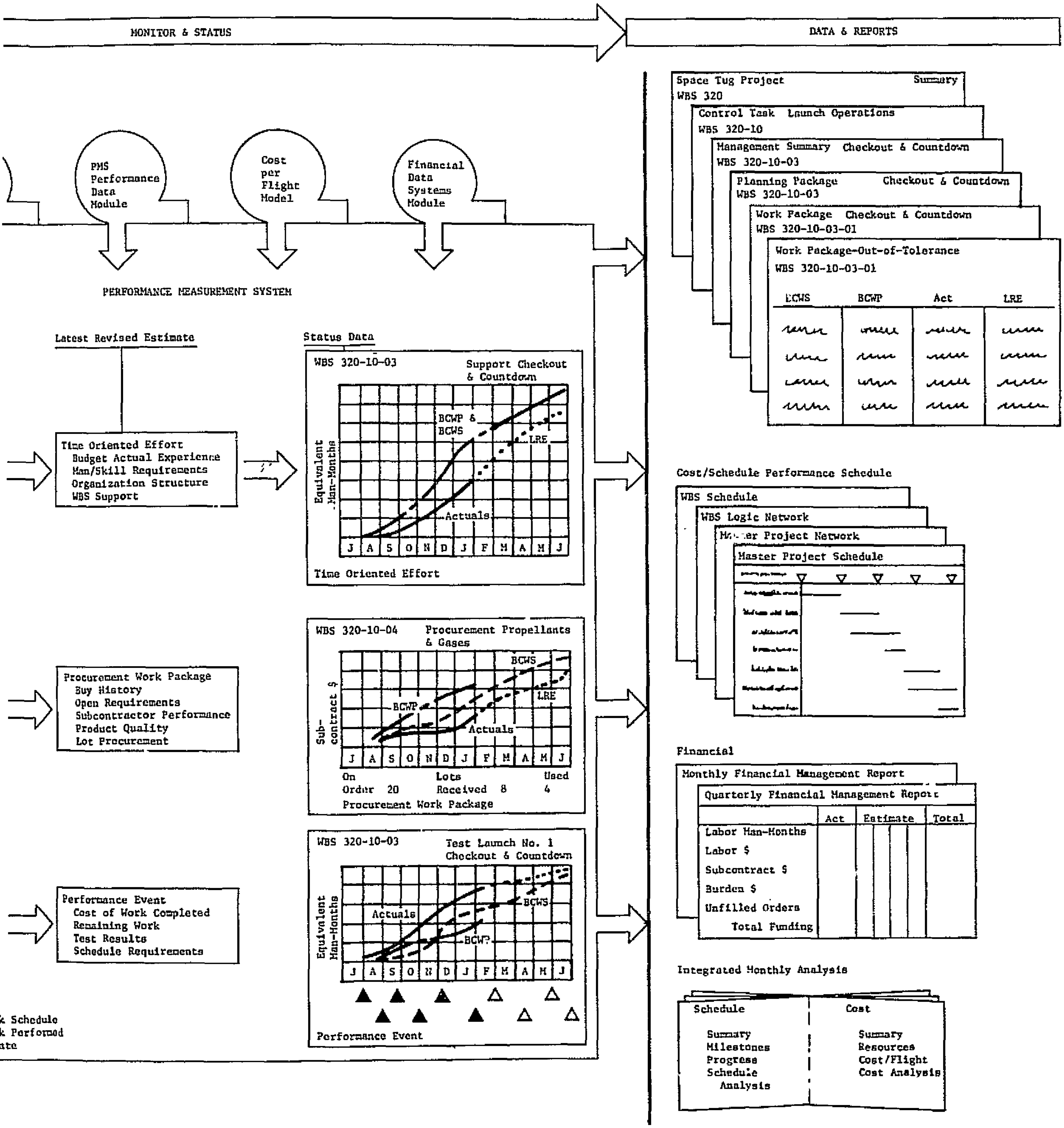

Figure III-B-26 Performance Status and Assessment

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4.1.9.2 Monitor and Status - The Performance Measurement System (PMS) will provide project and functional area management with mechanized summary and detail level time oriented cost tracking reports augmented by variance and out-of-tolerance cost data. Schedule status will be obtained manually from status meetings for all functional organization detail planning packages, and to supplement status for project level schedules obtained from the mechanized Tug Fleet Utilization Planning System. This system provides critical path data and other planning aids.

The PMS time related cost output is tabulated data with the shortest time element being monthly. The Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP), actual cost to date and Latest Revised Estimate (LRE), are shown. This data, when plotted, is particularly valuable for work package analysis and monitoring as previously discussed.

Schedule and cost data should be analyzed and iterated by management, as required, before monthly data and reports are finalized.

4.1.9.3 Data and Reports - The PMS will print-out time related cost data in a large variety of formats. One of the most useful shows BCWS and BCWP plan, actual cost, and cost variance for the current period and cumulative to date; and BCWS total and estimated cost and variance at completion.

This data can be developed at work package level and summarized at each higher control level through project level

Monthly statused schedule reports can be manually prepared to the NASA prescribed format from schedule and status data previously discussed.

Financial reports can also be manually prepared to NASA requirements from the mechanized PMS data.

An integrated analysis report that includes cost and schedule analysis should be prepared monthly. This report should be oriented toward analysis of performance and is keyed to problem identification, cause, corrective action, and impact at completion, with cost per flight included as an additional parameter to enhance performance visibility.

4.2 Tug Utilization Planning

Tug Utilization Planning can be dividied into Tug payload planning and Tug fleet utilization planning, as illustrated in Figure III-B-27.

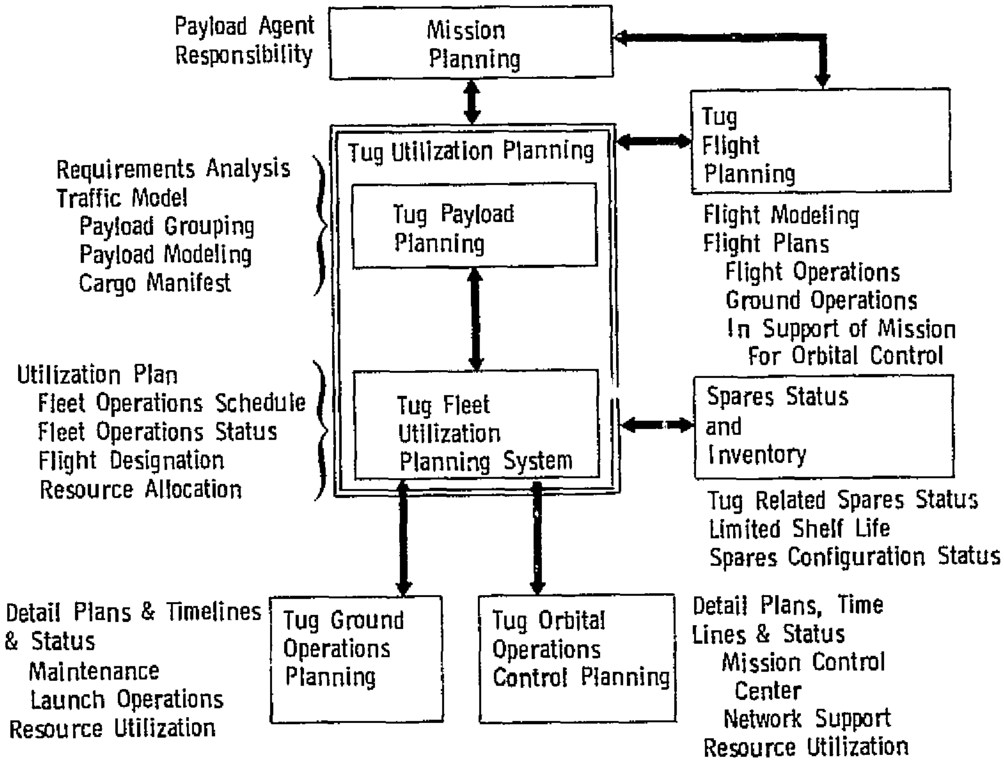

Figure III-B-27 Tug Utilization Planning

Tug payload planning includes analyzing payload interfaces with the payload agent and developing the Tug traffic model iteratively with the payload agents' mission planning and Tug flight planning. Mechanized systems exist, and more comprehensive systems are being developed to assist in this planning.

Tug fleet utilization should be iteratively planned with the three areas discussed previously, and with Tug ground operations planning, Tug orbital operations control planning, and the spares status and inventory to develop the project level utilization plan. This plan must be integrated with the STS/Shuttle plan.

The heavy payload traffic and long Tug operations program that is planned, the large number of parameters that must be considered for each mission, the changing mission priorities, and the necessity for rapid contingency and recovery planning establish the requirement for mechanized planning assistance. Because of the complex nature of the fleet utilization planning task, man must be kept in the loop to make the basic decisions.

Since the techniques for Tug payload planning are well established, only the concept for a Tug Fleet Utilization Planning System will be developed.

4.2.1 Tug Fleet Utilization Planning System - The Tug Fleet Utilization Planning System must be capable of providing tentative utilization plans or planning aids, must readily accommodate the input of changes, and must produce firm utilization plans and associated status data for different planning horizons and corresponding levels of detail in the format required for project implementation. This can be achieved by providing two computerized segments and two levels of data set inputs as diagrammed in Figure III-B-28.

The output of this system must be a cost effective utilization plan for the Tug fleet. This plan must define the fleet operations schedule and status in the detail required for project level control. It must designate the specific Tug and flight assigned to each payload and mission, and allocate resource levels.

To provide information that is essential for developing and maintaining the utilization plan, current information must be obtained by extraction from more detailed mechanized data bases and by manual input. Iteration with the more detailed planning areas will be required to develop firm plans for near-term operations.

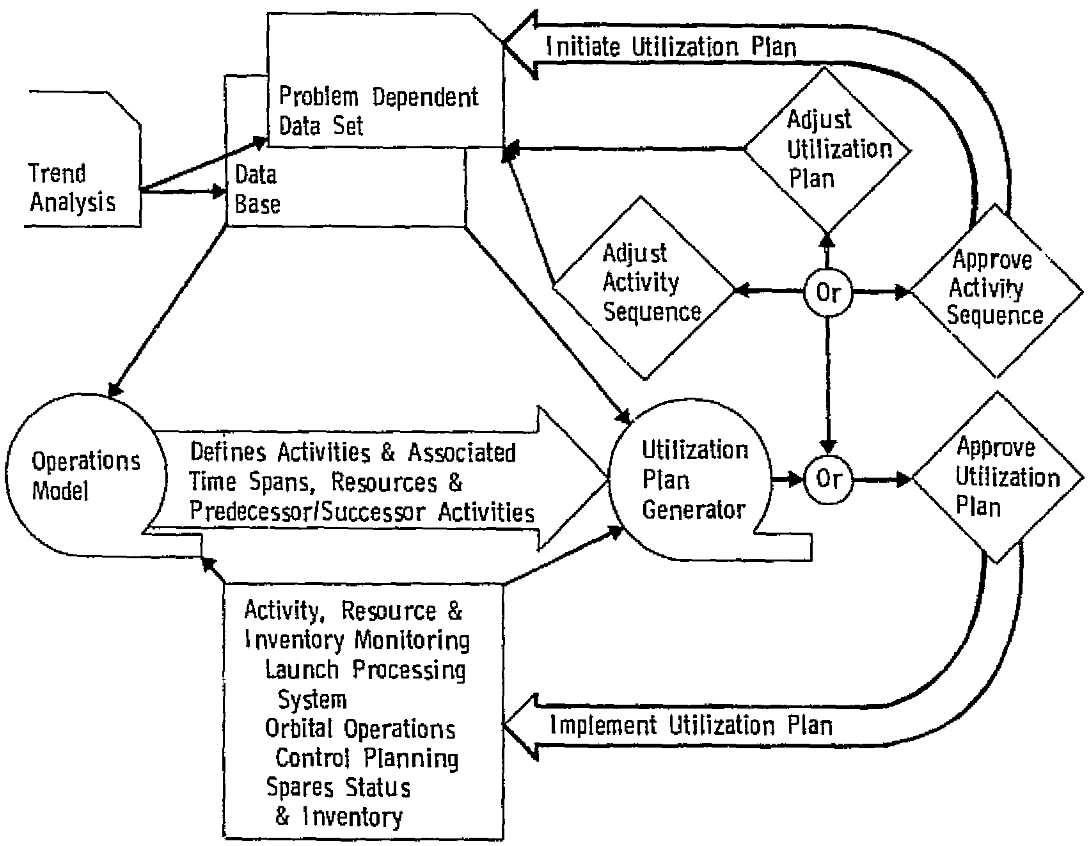

Figure III-B-28 Tug Fleet Utilization Planning System

This Tug Fleet Utilization Planning System concept would be compatible with the STS Payload/Space Laboratory Utilization Planning System being developed by MSFC and the flight scheduling subsystem for the STS Vehicle Management and Mission Planning System being developed by JSC.

4.2.1.1 *Operations Model* - The operations model is one of the two computerized elements of the Tug Fleet Utilization Planning System. It maintains an intermediate (lowest project) level description of Tug ground and flight operations. This description is configured so that less detail description levels may be selected by man. Included are the activities that might be required for a particular Tug flight (e.g., checkout software, mate payload to Tug), the resources available (e.g., Tugs, ground support equipment), and the temporal relationships between activities (e.g., completion of payload unloading before payload checkout begins). Each activity has, as a part of its description, its duration and the resources required to complete the activity. The description of the available resources may include the quantity, characteristics, and assignments made for each resource (e.g., certain payloads must be assigned to a pool of Tugs with specific modifications incorporated). The temporal relationships between activities may include simple predecessors or more general relationships, depending on the structure of the Tug operations.

In summary, the operations model defines for the utilization plan generator the following items:

1) Resources - Tugs, crew, parts, facility, GSE, etc.

    Quantity
    Characteristics
    Assignements to activities

2) Activities - checkout software, mate payload to Tug, etc.

    Activity durations
    Resources required for the activity

3) Relationship Between Activities

    Predecessors
    Successors
    General temporal relationships

The operations model must extract appropriate activity and resource data from more detailed data bases like the data base for the Launch Processing System (LPS), and be readily compatible with the less detailed operations descriptions used by the utilization plan generator. When a particular set of flights is to be scheduled, necessary information is extracted from the operations model

and provided to the utilization plan generator. Thus, changes to Tug operations that result from trend analysis must be input to the operations model. The primary feature of the operations model is that changes in the operations description are made as changes to the data base input, rather than algorithm changes.

4.2.1.2 Utilization Plan Generator - The utilization plan generator is the other computerized element of the Tug Fleet Utilization Planning System. It must be able to accommodate large operations consisting of many activities and resources, and be capable of producing tentative schedules quickly to support man-machine iterative planning. This indicates use of classical project scheduling techniques: a relatively simple model requiring inputs of activity durations and preceding/succeeding activity constraints, quantities of resources needed by activity, and available resource levels. Complicated resource characteristics (e.g., the requirement to specify the level of maintenance a Tug achieves after each activity) and temporal characteristics (e.g., the requirement to accomplish two launches within a maximum instead of specified or minimum time) are purposely eliminated. The program can then provide good tentative schedules with men resolving the conflicts that are difficult to express numerically.

Classical project scheduling will perform critical path analysis. Resource level constraints are recognized and temporal and resource related conflicts are detected and identified in the output. Contingency resource level considerations and resource smoothing capabilities are provided.

In summary, the general characteristics, input requirements, and output of the utilization plan generator are:

1) General characteristics -

   Uses classical project scheduling program;
   Accommodates large networks;
   Performs critical path analysis;
   Recognizes predecessor relationships and resource level constraints;
   Detects temporal and resource related conflicts;
   Considers contingency resource levels;
   Permits quick turnaround for man/machine iterations;
   Allows resource smoothing.

2) Input requirements -

   Peculiar problem requirements;
   Activity duration;
   Activity procedure constraints;
   Activity resource requirements;
   Available resource levels (normal and contingency).

3) Outputs -

Activity sequence;
Potential activity schedule (timelines);
Planning diagnostic data.

The utilization plan generator has a requirement similar to that of the operations model, for extracting status data from more detailed data bases like the LPS for Tug ground operations, and using it to obtain the less detailed data that are required for utilization planning. These data are used to status existing utilization plans and to show actuals for completed activities on new plans.

4.2.1.3 *Planning System Adaptability* - The intervention of man is essential if the Tug Fleet Utilization Planning System is to accommodate the continually changing planning requirements. The method recommended for providing the two computerized elements of this system with capability to readily accommodate changes in Tug operations requirements and planning levels is by input data set changes rather than algorithm changes. This is facilitated by dividing the manual input data into a problem dependent data set and a data base. The data base inputs the normal (green light or current utilization plan) logic into both computerized elements. The problem dependent data set inputs the additional data that will result in a specific plan. The problem data set will normally be changed for each tentative planning cycle. Trend analysis changes are input manually through the data set affected.

By using the manual input data approach described above, changes to operational networks, system resources, and planning horizons are readily accomplished and do not require algorithm changes.

Because the Tug Fleet Utilization Planning System should develop and status utilization plans, it is required during the preoperational phase to develop the initial utilization plans and during the operational phase for utilization plan maintenance which includes real time contingency planning.

Planning system adaptability can be summarized as follows:

1) Method independent of the operations model -

Accommodates changes to operational networks;
Accommodates revisions to system resources,

Quantities,
Addition or deletion of resources;

2) System accommodates varied planning horizons -

Long term, high level;
Short term, detailed.

3) System used throughout program -

Preoperational planning;
Operational (real-time);
Nominal and contingency.

4.2.2 Utilization Planning Horizons - The Tug Fleet Utilization Planning System should provide for a wide range in both planning horizons and level of detail. While planning should become more detailed as the horizon becomes shorter, planning needs can be roughly grouped in the following categories:

Firm Plans - Should cover approximately the next year with adequate detail for recovery planning at any time. This results in maximum detail for the next launch.

Intermediate Plans - Should normally cover approximately two years beyond firm plans to provide adequate time for long lead item identification. For some missions, the period may be much longer. Less detail is required than for firm plans, but sufficient detail for recovery planning should be maintained.

Soft Plans - Are needed for the projected duration of the program beyond the intermediate plans. Only the minimum detail required to define Tug ground and flight operations support for the longer range payload and flight modeling should be maintained.

Typical planning horizons are identified in Table III-B-6.

4.2.3 Utilization Planning Interfaces - The Tug Fleet Utilization Planning System interfaces are indicated in Figure III-B-27. When only intermediate to soft fleet utilization planning is required, the planning must be iterated with mission planning, Tug payload planning, and Tug flight planning. Mission planning requirements include desired launch timing and launch window restrictions. Tug payload planning provides the payload model, defines payload grouping and payload peculiar Tug equipment, and defines peculiar ground checkout requirements with associated GSE, software, facility, and training needs. Tug flight planning provides orbital operations schedules for control center and network activities, and defines peculiar orbital control checkout requirements with associated GSE, software, facility, and training needs. As the planning horizon increases, less detail is required but particular attention must continue to be given to the supporting payload and mission peculiar long lead items.

Table III-B-6 Typical Planning Horizons

Horizon	Cycle Time Basis for Horizon	Level of Depth
8 Years Soft	Duration of Projected Traffic Model	Top Level Planning
3 Years Intermediate	Nominal Payload Development Time	Payload Schedules and Milestones
1 Year Firm	Cargo Manifest Cycle	Required Accommodations
6 Months Firm	Nominal Integration Time at Development Center	More Detailed Facilities/ Resources
6 Weeks Firm	Nominal Spacecraft Checkout Time at Launch Site	Operations and Handling at Launch Site
157 Hours Firm	Nominal Tug Turnaround Time	Detailed Checkout, Maintenance, and Integration

For firm fleet utilization and recovery planning all of the above data must be kept current. Payload status must be obtained through the mission planning interface and the cargo manifest from Tug payload planning. Before approving firm plans, tentative planning must be iterated with Tug ground operations planning and Tug orbital operations control planning to obtain agreement that detail plans and timelines for maintenance and launch operations, and for mission control center and network support can comply with the fleet operations schedules and resource requirements. In addition, both areas provide program and hardware status.

The status of maintenance on each Tug is essential to both recovery planning and the assignment of a particular Tug to each payload and flight.

This status includes open items resulting from flight and ground checkout, and the grouping of Tugs into pools based on capability due to such things as modification status. Spares status and inventory data are required for each Tug in terms of spares shortage, limited and shelf life components, and spares configuration status.

Supporting facility and hardware status that affects fleet utilization must be current.

4.2.4 <u>Contingency Management</u> - Effective real-time contingency management requires thorough analysis of alternatives and prompt implementation of the revised utilization plan. The Tug Fleet Utilization Planning System previously discussed provides for the man/machine relationship that is needed to accomplish this.

Real-time contingency management uses man and computer in their most effective roles. This is illustrated by Figure III-B-29. Upon notification that a contingency has occured, man obtains a generic list of alternatives from the computer. He then assesses this list and rapidly determines the impact of all feasible alternatives by developing utilization plans for each using the mechanized system. He then selects the plan to be used and implements it after further detailing it with the mechanized system if required.

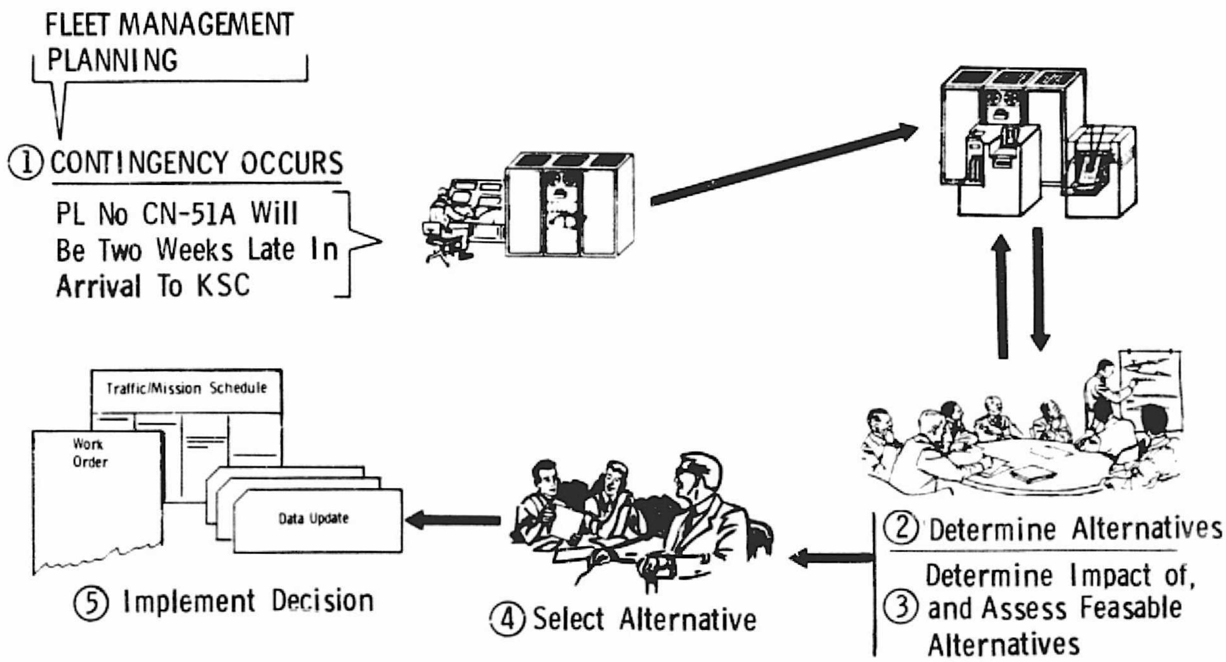

Figure III-B-29 Contingency Management Concept

4.2.4.1 *Contingency Analysis* - Contingency analysis should be implemented in the planning stage and requires real-time solutions involving rescheduling when a contingency occurs. The contingency analysis techniques illustrate the man/machine relationships involved in Tug fleet utilization planning.

The first step in the initial planning stage is to develop a tentative utilization plan with no contingencies (green light). This should be followed by tentative plans that incorporate the most likely and catastrophic contingencies. As a fallout of this process, a generic list of contingencies with alternatives for each should be stored in the computer for reference when a real-time contingency occurs. The tradeoff between expected risk,

time, and cost is then performed by management. The decisions are incorporated in the approved utilization plan to accommodate a reasonable level of contingencies with minimum program impact.

Real-time contingencies are handled in the same way, with the exception that the baseline is the approved utilization plan instead of the no contingency plan. Real-time contingencies generally affect only a relatively small portion of the utilization plan, but may revise the rest of the program.

Contingency analysis can be summarized as follows:

1) Develop contingency allowance for utilization plans -

   Determine green light schedule;
   Estimate most likely or catastrophic contingencies;
   Simulate effect of selected contingencies;
   Modify green light schedule.

2) Develop real-time contingency plans -

   Contingency occurs;
   Computer presents possible workaround alternatives;
   Man selects alternative courses of action;
   Computer simulation to determine effects;
   Man chooses desired alternative;
   Alter schedules accordingly.

4.2.4.2 *Real-Time Contingency Example* - An example of real-time contingency management will be discussed, assuming that Spacecraft CN-51A is two weeks late. This example shows the man/machine relationship that is involved in the recommended Tug Fleet Utilization Planning System.

When the utilization plan status report identifies Spacecraft CN-51A as being two weeks late, the Tug Fleet Utilization Plan computer is queried by manual input for the generic list of alternatives under the category - Late Spacecraft. A specific list of alternatives is then manually prepared and reviewed for feasibility and completeness. This is illustrated by Figure III-B-30.

After establishing feasible alternatives, each must be analyzed. Modifications are made to the manually input data base if required, and to the problem dependent data set for each variation of the feasible alternatives to be assessed. The input data is also revised to limit the output of the utilization plan generator to the minimum satisfactory detail level and to only the time phased portion of the utilization plan that is affected.

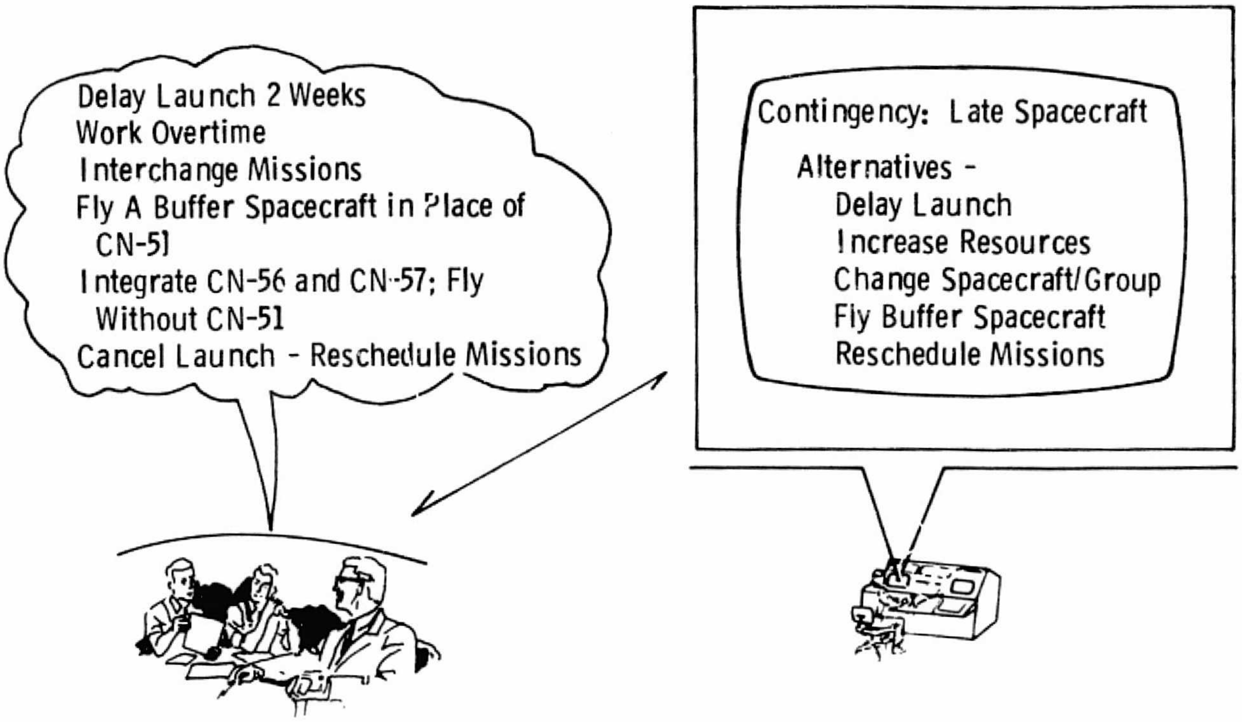

Figure III-B-30 Contingency Management - Determine Alternatives

The output data from the utilization plan generator can include: activity sequence so the program logic can be checked; planning aids such as critical path analysis; the effect of additional resources and resource smoothing; diagnostic data identifying temporal and resource related conflicts; and tentative utilization plans. During the preparation of these tentative plans, data are iterated with the other planning areas, including STS/Shuttle planning, as required for the detail being considered. These data are reviewed, and the plan to be implemented is defined. Alternative assessment is illustrated by Figure III-B-31.

Data are manually input for final changes to the utilization plan and to provide for the normal level of detail in the firm utilization plan. Iteration with other planning areas is then extended to this increased detail level, and the resulting approved plan is implemented as a revision to the existing utilization plan.

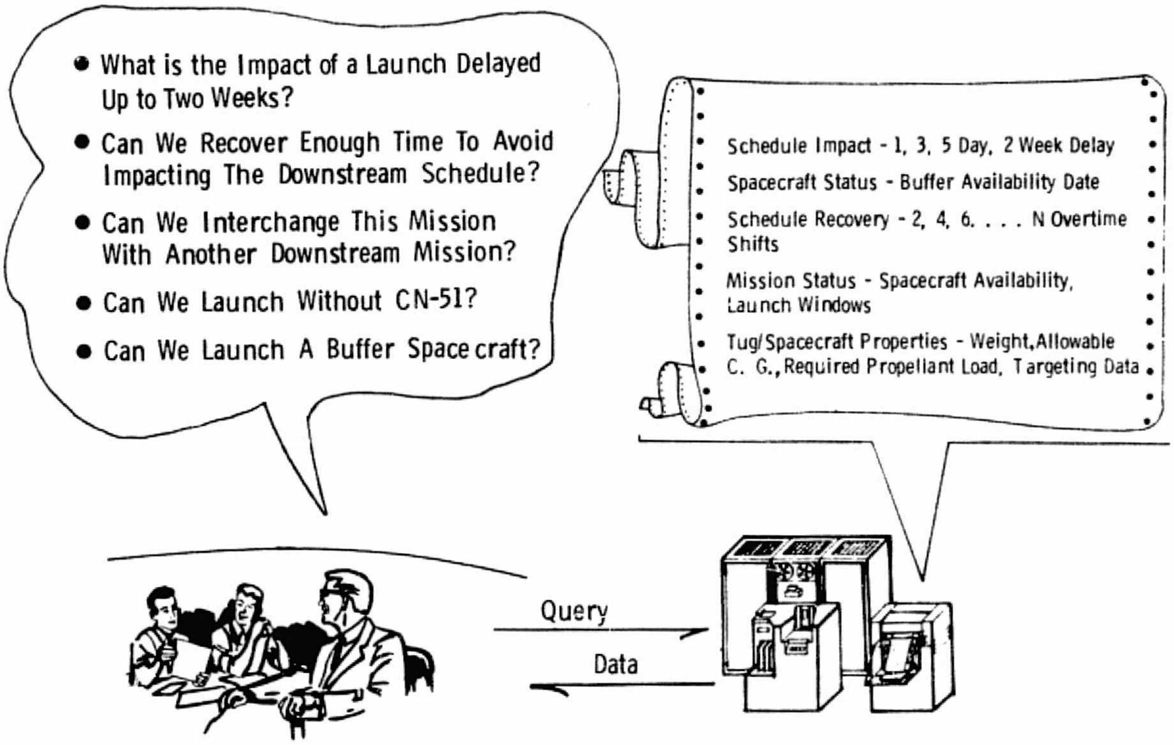

Figure III-B-31 Contingency Management - Assess Alternatives

4.3 Configuration Management

Configuration Management provides the necessary procedures and disciplines to achieve effective control over the hardware, software, and operational activities of the Tug ground operations project. This control is needed on a continuing basis throughout the life of the project. The objective of Configuration Management is to ensure the maximum operational capability through formal initial identification of configuration, controlled approval of changes, and continuing and accurate recording of the exact configuration of systems and selected equipment. Recommendations for implementation of configuration management, basically a conventional implementation system as reflected in MSFC Document MM 8040.12, Standard Contractor Configuration Management Requirements that has been proven to be effective are discussed in this section. In addition, the recommendations are in consensus with JSC Document 07700, Volume IV, Rev A, Space Shuttle Program Level II Configuration Management Requirements and KSC Document K-SM-04.1, Instruction for Processing Changes to Validation Baseline Station Set Requirements Documents.

4.3.1 Configuration Management Responsibilities - The Configuration Management organization should retain the overall responsibility and authority to implement and control configuration management activities for the Tug ground operations program. These responsibilities should include performing or participating in the following activities:

4.3.1.1 *Identification* -

1) Specification - Provide formats, coordinate required inputs, and submit for baseline end item specifications. Monitor and review the preparation and submittal of lower tier specifications.

2) Interfaces - Coordinate interface activity. Attend interface meetings, coordinate requirements among support equipment design organization/contractors and provide the focal point for interchange of information between interfacing activities. Track and schedule resolutions of interface requirements.

3) Program Documentation - Prepare, coordinate, and maintain a Project Configuration Management Plan. Audit required documentation to assure compatibility with project and program requirements. Track and status milestones associated with preparation and submittal of required data.

4.3.1.2 *Baseline Management* - Identify approved baseline documentation to support baseline reviews, and participate in these reviews to assure approved baseline requirements are being implemented in designs. Track and status action items and Review Item Dispositions (RIDs) resulting from reviews.

4.3.1.3 *Change Control*

1) Establish Configuration Management change processing function and a Configuration Control Board (CCB) for processing changes.

2) Provide secretary for CCB.

3) Participate in coordination of change evaluation and effect development of a total engineering change package.

4) Prepare Configuration Control Board Directive (CCBD) to direct and authorize change implementation.

5) Provide support to Level II Program Requirements Change Board (PRCB), Level III, and Level IV CCB.

4.3.1.4 *Status Accounting and Verification*

1) Maintain the status of the project baselines through a system such as MSFCs Standard Change Integration and Tracking/Configuration Management Accounting (SCIT/CMA) systems.

2) Provide necessary status accounting reports to support reviews, configuration inspection, acceptances, and turnover of hardware items.

3) Provide open items and history tab runs to support project activities.

4.3.1.5 *Subcontractor/Supplier Requirements* - Audit subcontractor to assure that subcontractor's Configuration Management System is compatible with minimum requirements established by MSFC.

4.3.1.6 *Level IV Configuration Control Board (CCB)* - Establish NASA Design Activity/Contractor Level IV CCB for those specifications, drawings, and other documents released through the NASA Design Activity/Contractor's documentation release system. Changes to these documents that do not affect Level I, II, or III documentation should be controlled through the Level IV CCB.

4.3.2 Configuration Identification - Configuration identification is accomplished by documenting the technical and project requirements in specifications, interface control documents, plans, and drawings. Configuration identification for the Tug ground operations project must be accomplished through development of formal documentation that will describe the baseline to be used for control and accounting of future changes. It is recommended that an interface between the several NASA Centers, DOD agencies, element contractors and payload contractors be established early in the program to exchange apporpriate information for incorporation into the Tug ground operations system.

Figure III-B-32 generally illustrates the interrelationship of NASA and DOD Shuttle/Tug documentation. Documents that reflect Tug ground operations requirements must be compatible with the requirements of the Level I and II documents. The following reflects the recommended level of control which is generally established in JSC 07700, Volume IV, Revision A.

4.3.2.1 *Level I Documentation* - The contents of these documents are the responsibility of the NASA/DOD program director(s) and contain only program level requirements (i.e., those applicable to the program as an entity) and may contain, as an example, the following types of data: program definition, characteristics, interface, and verification requirements.

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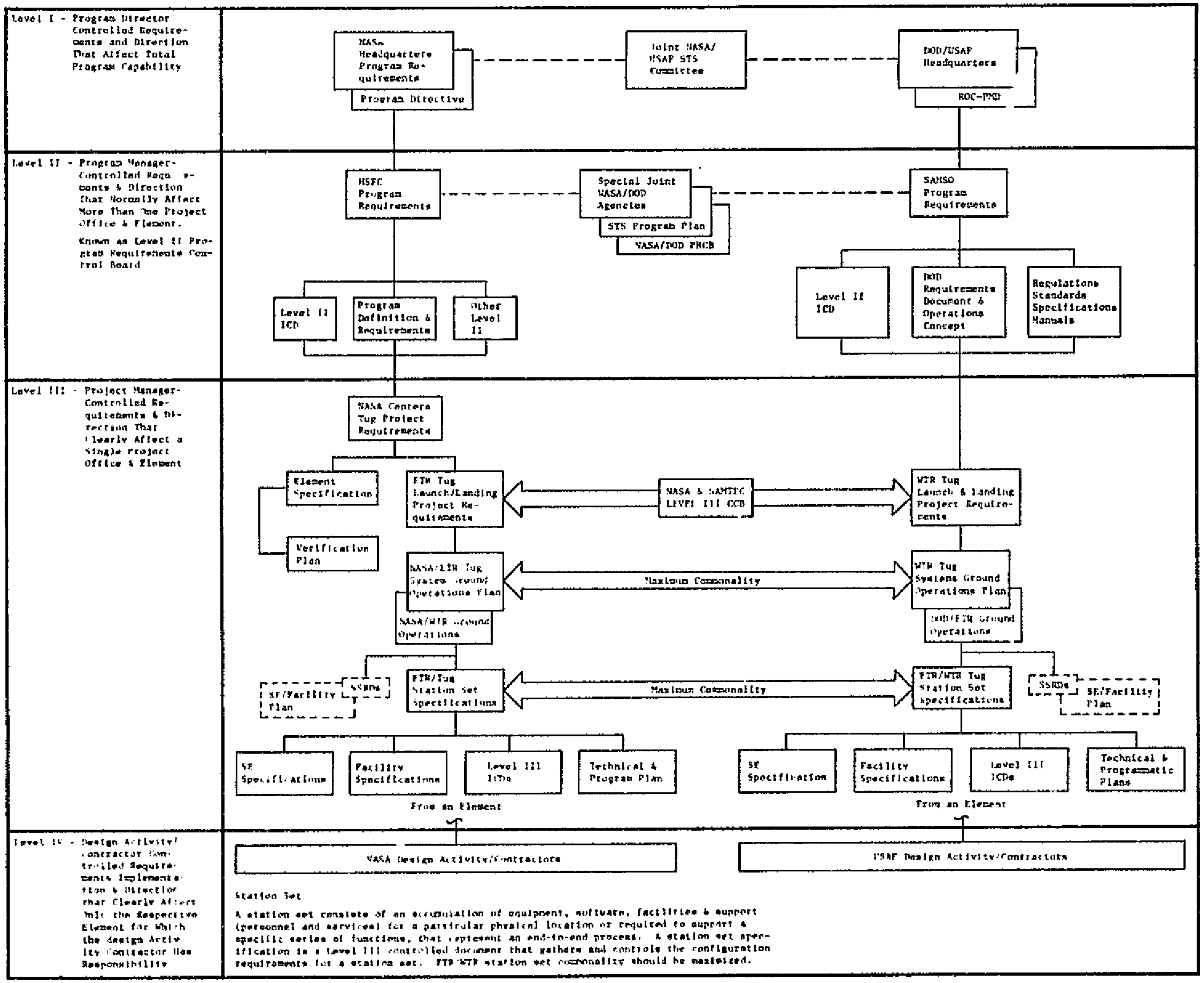

Figure III-B-32 Interrelationships of NASA and DOD Requirements Documents

4.3.2.2 Level II Documentation - These documents identify performance, design, interface, and verification requirements for each of the project elements of the Space Transportation System; they affect more than one project office/element and are the responsibility of the program manager and the Program Requirements Change Board. This documentation may contain the following types of data:

1) Level I requirements,

2) System responsibility allocations,

3) System schedules,

4) System budget and cost allocations,

5) Management system requirements,

6) Information requirements,

7) System design and performance requirements,

8) System interface requirements, excluding interfaces to be controlled by a single project office,

9) System verification (acceptance, certification) requirements,

10) Commonality requirements,

11) Standard design and construction requirements applicable to the total system,

12) Other applicable allocated requirements,

13) Training requirements.

4.3.2.3 Level III Documentation - These documents specify the configuration identification of the system elements and relate system and element requirements in the areas of performance, design, interface, and verification, and are the responsibility of the appropriate individual project managers. This documentation may contain the following types of information.

1) Level I and II requirements,

2) Design and construction standards and specifications,

3) Station set specification (functional and operational),

4) Interface documents,

5) Facility design criteria,

6) Ground operations plan(s),

7) Station set requirements document(s),

8) Configuration item development specification,

9) Computer program development specifications,

10) Facility installation specification,

11) Program plan (including verification and logistics requirements).

4.3.2.4 *Level IV Documentation* - These documents are Design Activity/contractor prepared specifications, drawings, and other documents released through the Design Activity/Contractor's documentation release system. Changes to these documents that do not affect Level I, II, or III documentation are controlled through the Design Activity/Contractor's Level IV Configuration Control Board (CCB). This documentation may contain the following types of information:

1) Contractor design criteria,

2) Contractor internal specifications (i.e., process, material and procurement),

3) Drawings (before configuration inspection),

4) Contractor internal plans and procedures,

5) Design concepts, approaches, and solution at the appropriate time.

4.3.2.5 *Project Documentation* - The project requirements and criteria should be accomplished through formal documentation in a format generally required by MSFC Document MM8040.12. These documents, when approved by the project, will establish the baselines for the control and accounting of all changes thereto. Formal project documentation may consist of those items identified in para 4.3.2.3.

In the interest of economics and commonality of design and equipment, documentation already in existance should be used "as is", or updated by change or appendixes to reflect the project requirements.

It is recommended that these documents be controlled through the NASA Design Activity/Contractor Level IV CCB before implementation of the activation/hardware acquisition phase. Subsequently, these documents will be controlled through the Level III CCB.

4.3.3 Configuration Control - Procedures for processing changes vary depending on what agency/contractor has document responsibility, status of the document (formal baseline, technical baseline, or prebaseline) and the document level of control. The following possibilities exist:

1) Common NASA/DOD Level I and II Baseline Document

2) NASA Level III CCB Baselined Document

3) NASA Level III Technical Baselined Document

4) DOD Level II/III CCB Baselined Document

5) NASA Design Activity and NASA/DOD Contractor Level IV Baseline Document

4.3.3.1 Change Processing Forms - For ease of processing change packages to the applicable NASA/DOD CCB, it is recommended that a standard format be used. When reviewing applicable NASA forms and comparing these forms with the DOD forms contained in MIL-STD-480, we find information required by each form is similar. Therefore, a common format would be feasible.

4.3.3.2 Processing Changes to NASA/DOD Baseline Requirements [Ref Para 4.3.3.1), 2) and 4)] - The recommended methods of processing change requests to NASA and DOD controlled baselines are illustrated in Figures III-B-33 and III-B-34. Changes may be initiated by any NASA/DOD design activity or contractor. In the event the change is initiated by a NASA contractor, the technical review must be with the appropriate NASA design activity. Likewise, if the change is initiated by a DOD contractor, the technical review should be with the appropriate DOD command. NASA initiated changes should be provided to DOD for impact assessment. DOD impact would be provided by the DOD CCB representative.

4.3.3.3 Processing Changes to NASA Level III Technical Baseline Requirements [Ref Para 4.3.3.3)] - The recommended method of processing change requests to NASA Level III technical baselined requirements is illustrated in Figure III-B-35. With this method, the change may be initiated by the NASA design activity or contractor as well as other project elements and DOD agencies. This type of change should be processed using the Review Item Disposition (RID) form. In the event the proposed change affects a Level I or II requirement, the appropriate Level I or II change request must be initiated for processing the total change package by NASA to the applicable Level II PRCB for disposition. This change flow is in consensus with KSC document K-SM-04.1.

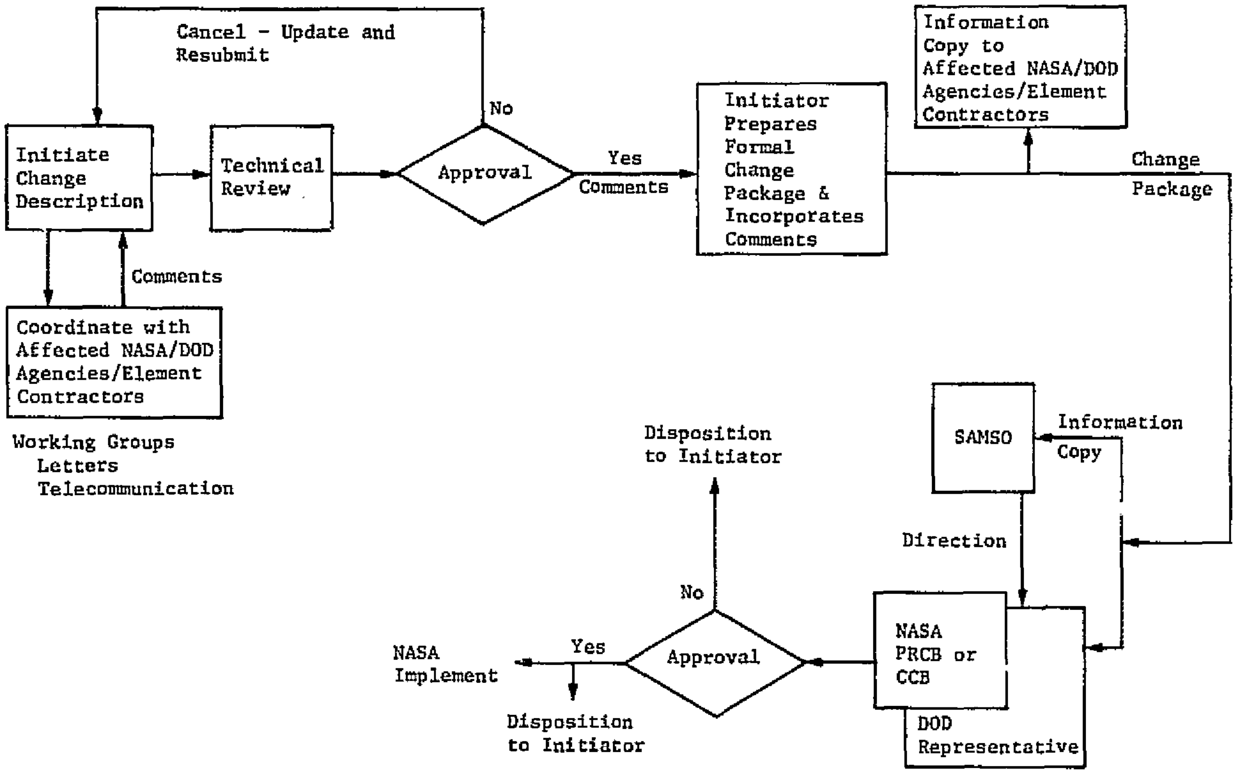

Figure III-B-33
Method of Processing Formal Change Requests to NASA Program/Project Controlled Baselines

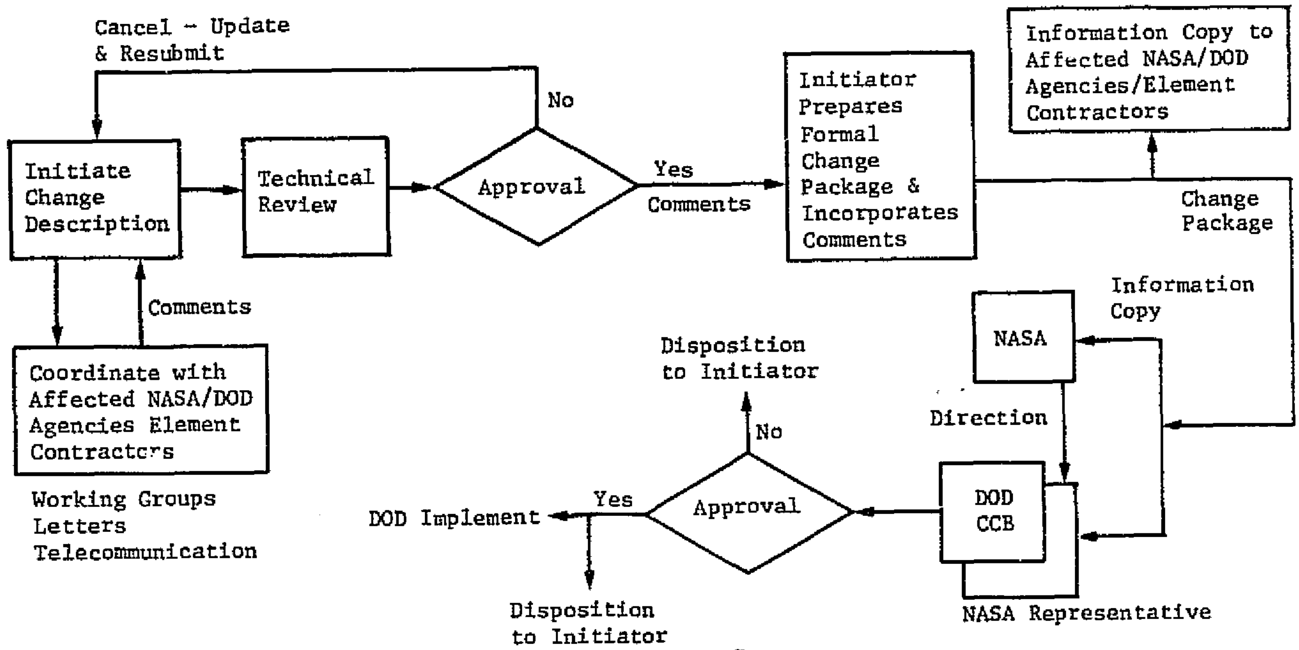

Figure III-B-34
Method of Processing Formal Change Requests to DOD Program Controlled Baseline

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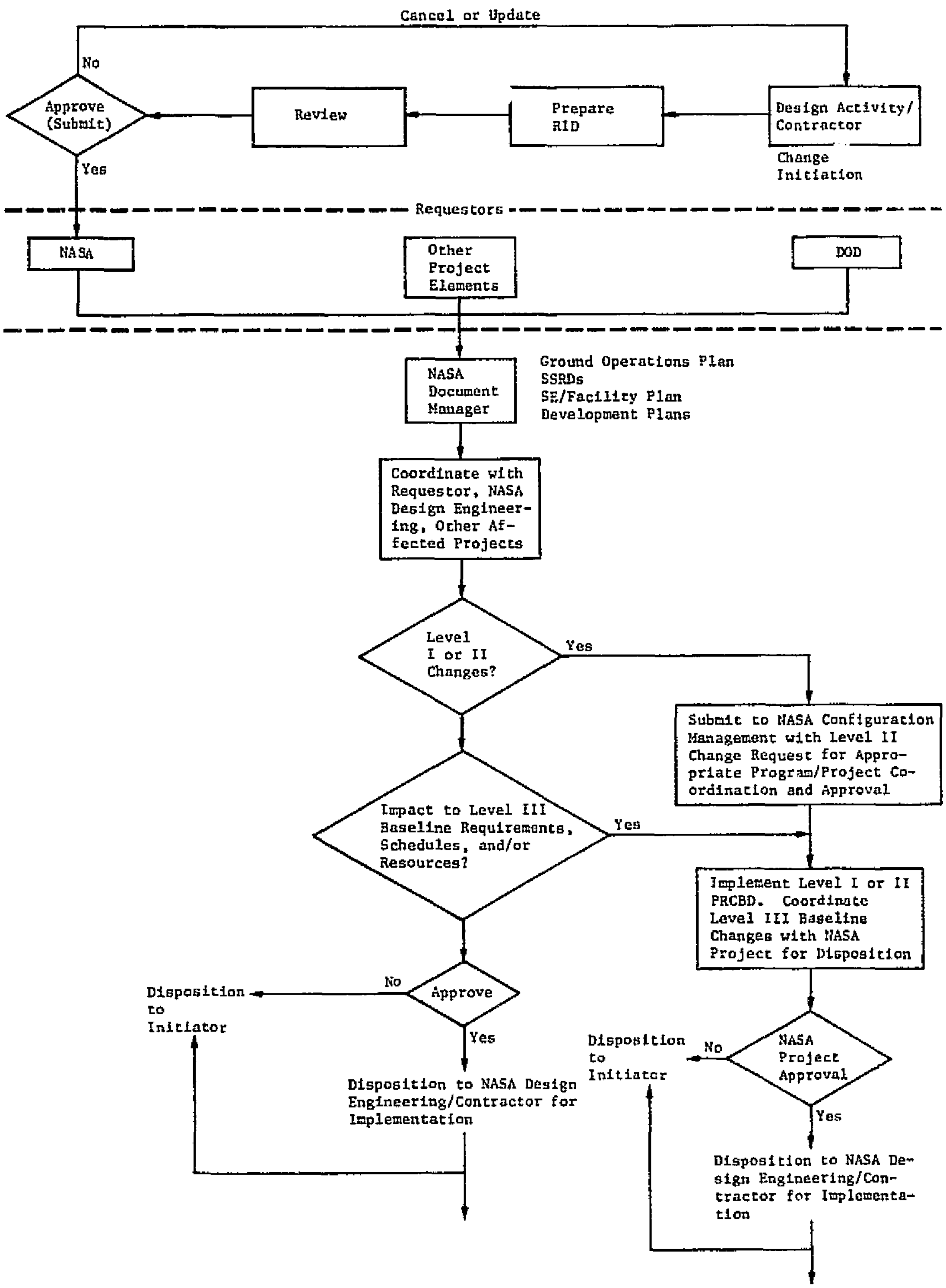

Figure III-B-35
Method of Incorporating Tug Ground Operations Requirements into NASA Level III Technical Baselined Documents

4.3.3.4 Processing Change to NASA Level IV Controlled Baseline [Ref Para 4.3.3.5)] - The recommended method of processing change requests to NASA Level IV controlled baselines is illustrated in Figure III-B-36. This method is an efficient and disciplined system that will assure the proper amount of coordination and evaluation. The initiator may be any program/project element, contractor or DOD agency.

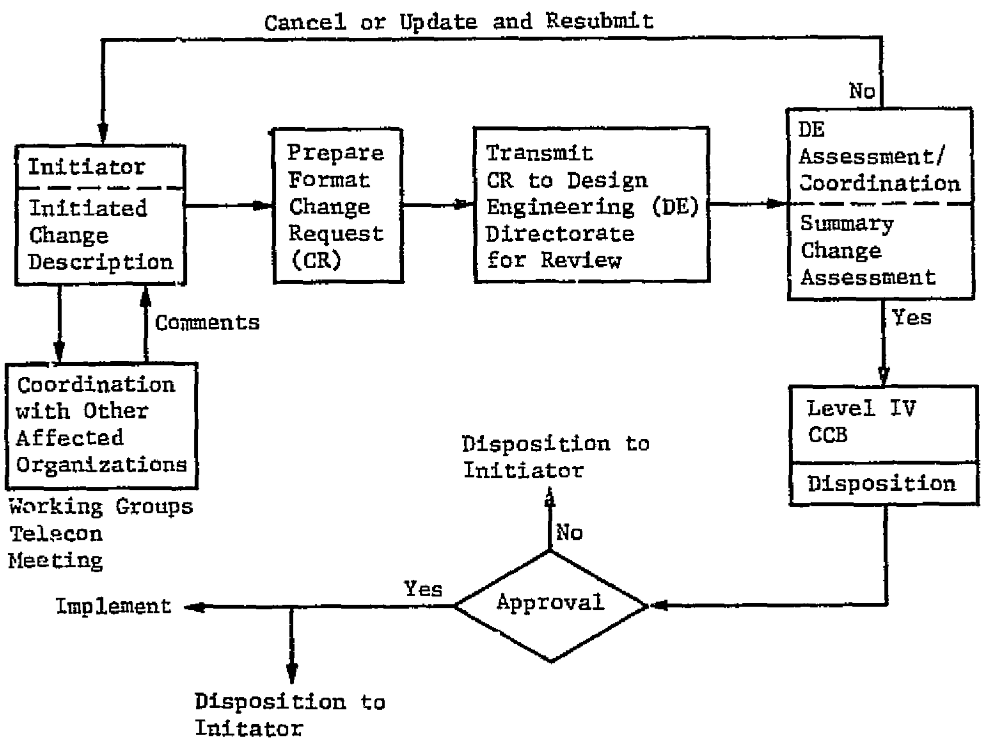

Figure III-B-36
Method of Processing Change Requests to NASA Level IV Controlled Baseline

4.3.3.5 Processing Changes to a Contractor Level IV Controlled Baseline [Ref Para 4.3.3.5)] - A change management system should be levied on NASA prime contractors that will complement the total NASA change management approach. The contractor should maintain a disciplined system for control of changes to established baselines. The change management technique used for control of changes, including Level IV changes as well as Level II and III changes, and subtier supplier changes, must assure all changes are properly coordinated, evaluated, documented, and processed, and ensure that only those changes approved for incorporation are implemented as authorized. The contractor Level IV Configuration Control Board (CCB) should be the focal point for all change processing.

4.3.4 Verification and Acceptance

4.3.4.1 Closed-Loop Change Incorporation/Verification Process - A closed-loop change incorporation and verification processing system is recommended. This system as illustrated in Figure III-B-37 proved very effective. The verification process assures hardware compliance with the NASA baseline documentation requirements. It also verifies that only approved changes are incorporated into hardware and documentation as authorized. Configuration traceability is maintained through this system. Some of the salient features of the closed-loop verification process are listed.

1) Released basic engineering and changes are verified to be in compliance with the Project requirements.

2) Released engineering is verified as incorporated into the hardware during production.

3) Released engineering for retrofit modifications is verified as fully incorporated into modification kits.

4) Retrofit modification kits are verified when fully installed in the hardware.

5) Noncompliances are identified and remain as open items until resolved.

6) Configuration status records provide complete comparisons of verified as-built versus as-designed configurations.

4.3.4.2 Hardware Acceptance - It is recommended that acceptance of each deliverable ground support equipment end item be accomplished at the manufacturing facility before delivery of the end item to the using site. This will facilitate the activation process at KSC/VAFB.

4.3.5 Contractor Control - It is recommended that NASA levy on contractors and suppliers limited to hardware or software items, only those requirements necessary to maintain the required level of configuration control of the design, fabrication, and acceptance. The level of configuration management imposed on procured items should be evaluated with respect to the amount of development, design, and testing required.

4.3.6 Status Accounting - An effective and functional status accounting system should be established that would provide complete and current visibility of approved baselines, a record of change authorization and incorporation, hardware as-designed and as-built comparisons, as well as special reports. The status accounting system should be similar to MSFC's SCIT/CMA system.

Figure III-B-17

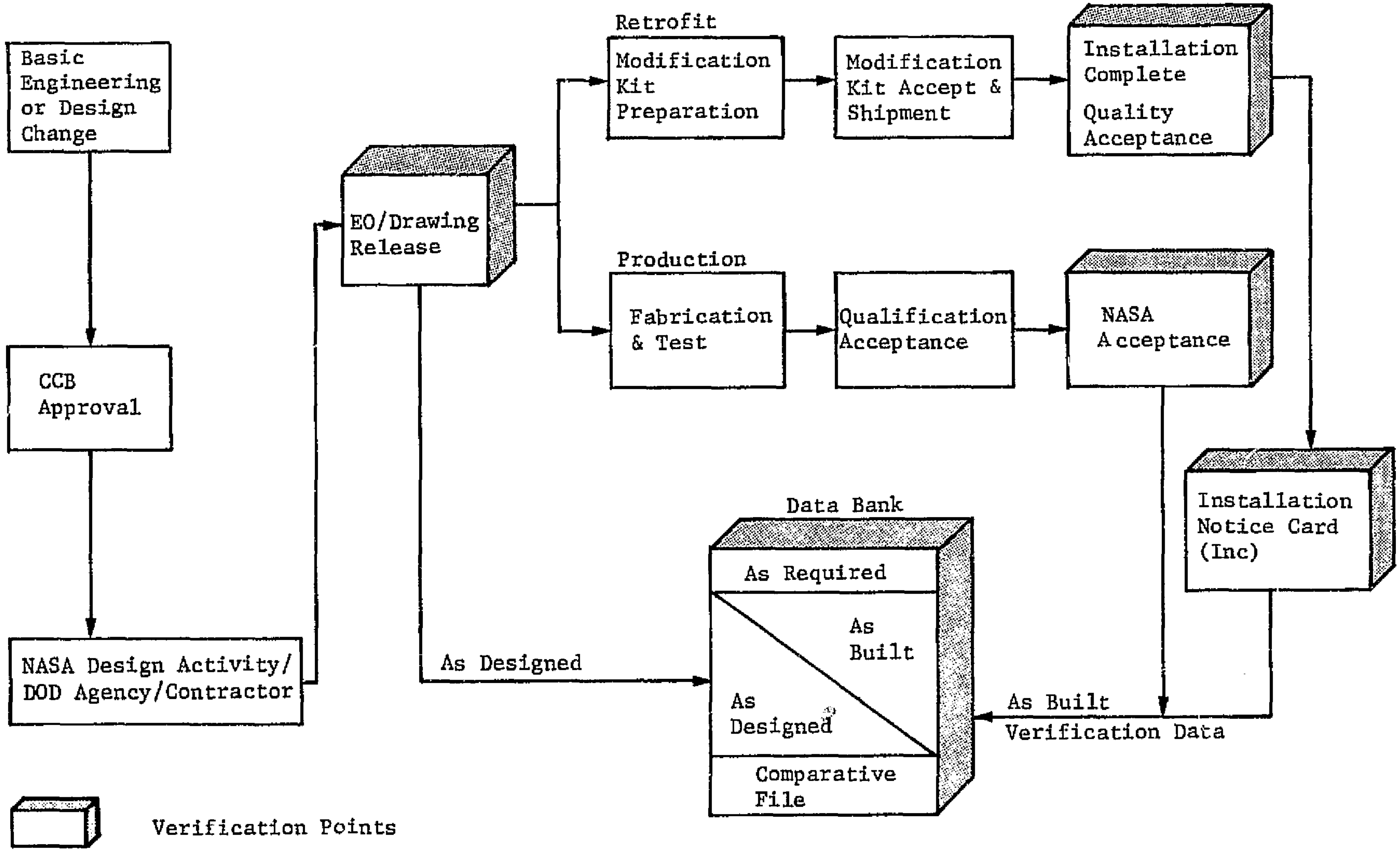

Figure III-B-37 Change Incorporation and Verification

4.4 Information Management

The purpose of Information Management is to assure that all information developed is necessary, compatible with program requirements, available to users, and properly maintained and controlled. Project level information requirements, control and retrieval, and the MSFC Tug Management Information Center as it relates to fleet utilization and ground operations, are discussed in this section.

4.4.1 Information Requirements - Project level information will be produced by all project participants. Requirements should be developed to ensure that this information is compatible for consolidation or use at project and STS level. Data requirements should assure that both development and operational needs are met with minimum cost and schedule impact. Existing reports and formats should be used where cost effective.

Types of information and a unique numbering system for each item should be defined to assist in establishing information requirements at project level. A documentation tree should be developed that identifies those documents recognized by the project office and authorized for development as required to fulfill project objectives. In addition, a list of requirements for information products to be submitted to the project office for approval, for information, or only on request should be developed. This list should be supplemented by suitable descriptive data for each information requirement. When information is to be developed by a contractor, the data requirements in the Data Procurement Document should be developed from this master list and descriptive data. We recommend that information types be those defined in JSC 07700, Vol V, para 4.0, and that the project information requirements be compatible with para 7.0 Space Shuttle Level II information requirements. It is particularly important that the numbering system be compatible.

Subsequent to the initial development of the project information requirements, a continuous review of information activities should be performed to assure that requirements are maintained current and valid.

4.4.2 Information Control and Retrieval - The frequent launch of different payloads and the rapid turnaround and reuse of Tugs require efficient information handling. In selected areas, this can best be achieved by mechanization.

Schedules for development and maintenance of data should be implemented and statused. All project data scheduling should be interfaced with STS and payload schedules for related data to assure timely availability.

An accurate mechanized accession list of all types of significant information produces should be maintained along with procedures for obtaining the listed information. Information producing activities should be responsible for storage so that data are readily retrievable. This includes studies and analyses that are the basis for program decisions and historical information. The development of the Space Shuttle Program Information Control and Retrieval Systems should be monitored to assure compatibility with the corresponding systems used for the Tug. Document JSC 08100 is the management plan for establishing and managing this system.

An information distribution matrix should be developed and maintained that provides for minimum normal distribution by primary users. Additional distribution should be by request on an accessioning basis.

The phased implementation of Information Management is illustrated by Figure III-B-38.

4.4.3 Management Information Center (MIC) - An austere type effective and functional Level III MIC for the Tug Project should be established at NASA. It is recommended that the permanent displays and data maintained in this MIC be limited to that required for top level reviews by NASA, other NASA centers, NASA headquarters, payload users and USAF and DOD management personnel. Adequate provisions should be made for reviewing working level data maintained in the Project functional areas and communication with all program participants as required for NASA management decisions.

It is recommended that the MICs for fleet utilization and ground operations at KSC and WTR be limited to the display of selected working level data as required for operating control. It is anticipated that SAMSO will have an MIC that will be compatible with other Tug fleet utilization and ground operations MICs. The following MIC recommendations are for the Tug fleet utilization and ground operations portion of the NASA Tug MIC.

4.4.3.1 Display Methods - The following display methods are recommended:

1) Panel Displays - A prominantly displayed magnetic panel and supply of suitable magnetic chart material for near-term fleet utilization plan display, and fixed and/or sliding panels for other primary displays.

2) Program Reference Data - Maintain current hard copies of selected program reference data located convenient to the related panel displays.

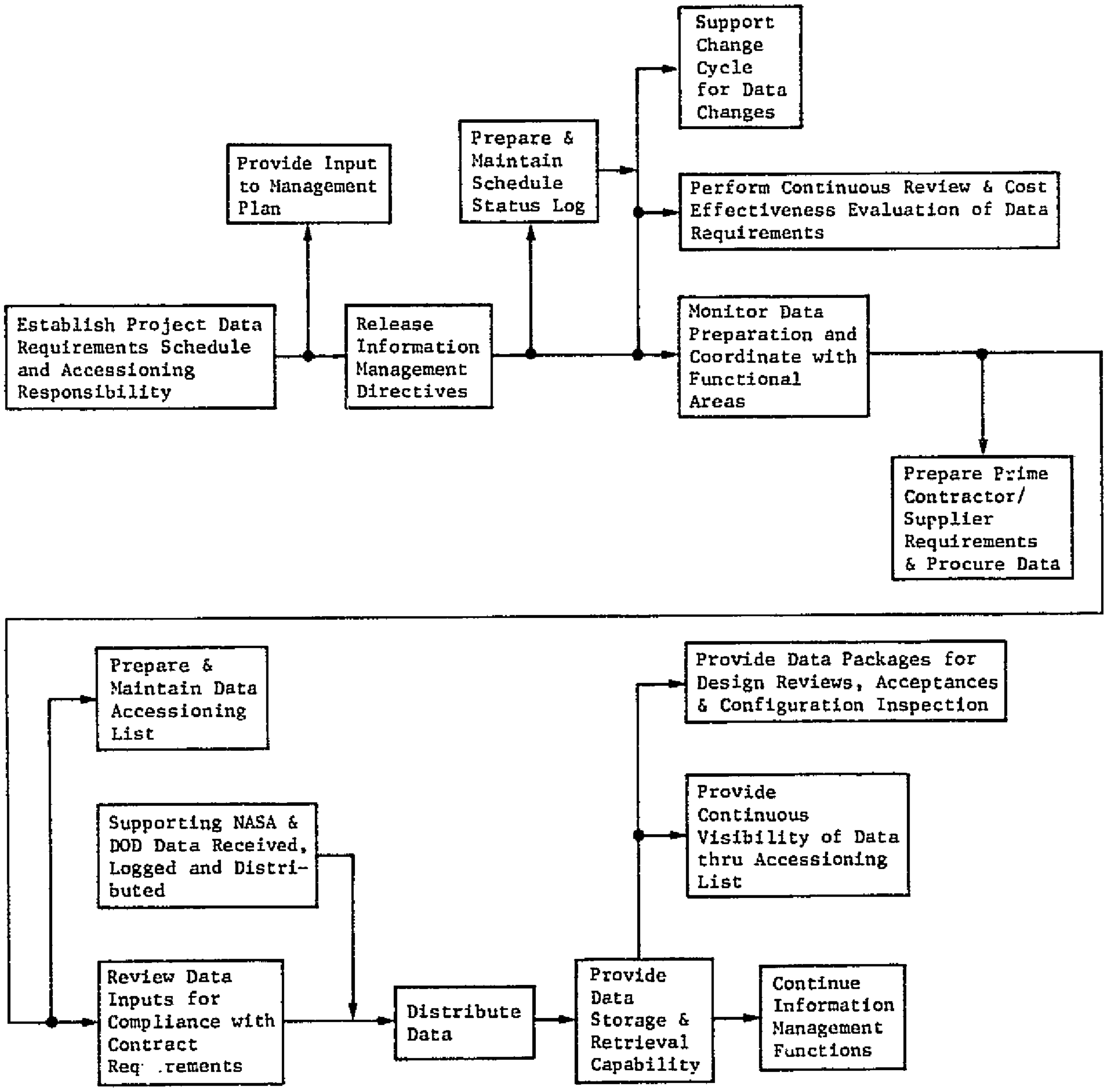

Figure III-B-38 Phased Implementation of Information Management

3) Projected Displays - Provide a dual screen projection system suitable for viewgraphs, 35-mm slide and 16-mm motion picture projection--preferably from the rear of the screen.

4) Blackboard - Provide a blackboard for "chalk talks".

4.4.3.2 *Meeting Accommodations* - A conference table and chairs should be provided along with additional seating for presentations.

4.4.3.3 *Teleconference* - The primary communications system between MICs should be the 4-wire, dedicated circuit, NASA teleconference network with the Bell 50-A conference unit or equivalent as a backup.

4.4.3.4 *Data Transmittal* - A DACON, or similar facsimile system, should be convenient for transmittal of hard copy images between MICs. A 24-hour, or less, mail service should also be established between MICs.

4.4.3.5 *Graphics Standards* - It is desirable to adopt the graphics standards defined by document JSC 07700, Vol III, Attachment B, para 4.1.5 where applicable and cost effective.

4.4.3.6 *Display and Data Maintenance* - All displays and data should either be maintained currently, or the frequency of revision and date of last revision should be noted. If the display or data is under review or revision, this should be identified.

4.4.3.7 *Reproduction* - Capability should be provided to convert any MIC display to a black and white print, to a black and white or color 35-mm slide, or to a black and white or color viewgraph. Zerox, or equivalent equipment, should be convenient for rapidly reproducing printed material or making viewgraphs.

4.4.3.8 *Display Requirements* - The following charts and data are suggested for display for the Tug Fleet Utilization and Ground Operations Program:

1) Wall or fixed panel displays -

- Magnetic chart board display of the firm fleet utilization plan by weeks for four months, with a maximum of one month of actuals;

- Panel display of the fleet utilization plan summarized by quarter for a minimum of three years and by half year for the remainder of the program;

- Payload model (matrix);

- KSC ground processing schematic;

- WTR ground processing schematic.

2) Sliding panel displays -

- Summary program schedule;

- Summary program logic diagram;

- WBS diagram (with a hard copy of the dictionary in adjacent rack);

- Summary end item delivery schedule;

- Summary software development and integration schedule;

- Summary activation schedules - KSC and WTR;

- Summary Logistics schedule;

- Key issues and problems (with hard copies of current reports in adjacent rack);

- Project activities calendar;

- Financial summary and cost for flight;

- Summary of configuration management status.

3) Projected displays - Projected displays usually involve data that are either restricted or of a more detailed nature that is reviewed by appropriate personnel. The most cost effective way to provide such data is to maintain and store it in the area responsible for its development. Data required in normal day-to-day operations should be used for this purpose where possible. Data categories suggested for projected display upon request include:

- Configuration management status by change;

- Technical data (weight, performance, etc);

- Major hardware schedules by end item;

- Software schedules by end item;

- Program performance data (from the Performance Management System discussed in section 4.1);

- Prime contract and major subcontract data;

- Financial data;

- Program management relationships and organization charts;

- Flight (including Tug payload) and ground system integration data;

- Facilities data;

- Logistics data (spares, technical manuals, training and training aids, and transportation and handling);

- Tug fleet utilization schedules (from the Tug Utilization Planning discussed in para 4.2).

4.4.3.9 Project Status/Progress Photographs - Photographs of important activities, events, and hardware should be properly identified and kept in convenient storage.

4.4.3.10 MIC Update Procedure - A systematic procedure for identifying current data and a brief description of the latest change should be implemented. This system should also be used to assure that the same data is displayed in all MICs when applicable.

4.5 Logistics Management Operations

NASA logictics management for Tug must provide direction and control of the interfacing elements of the logistics function during the life of the project, including preparation and maintenance of the Tug Integrated Logistics Support Plan; development and refinement of the Support Requirements Analysis; coordination of logistics requirements between NASA, the Tug contractor, and various suppliers; development of logistics milestones and scheduling of activities; and effective planning and implementation of resources.

The concepts of refurbishment and reuse of the Tug, as well as other elements of the STS, adds a new importance to the planning, implementation and control of logistics support. The requirements imposed by both the turnaround timeline and the Shuttle program budgetary constraints demand total Tug support planning. Interfacing Shuttle program elements, as well as the multiple considerations of the planning and operational phases, must be considered. Application of optimum logistics management techniques, established or innovative, is essential to the objectives and policy of Vol XII, 07700, Shuttle System Level II documentation.

The Logistics Support Requirements Analysis (SRA) is the initial and most important management tool needed to assess the interfacing impact of system and phase logistic elements and to avoid downstream problems through early identification of requirements in the definition and design phase. This approach to the logistic process, illustrated in Figure III-B-39, has been used extensively in the development of this study and should continue to be used by NASA and its Tug development contractor to refine and mature support system concepts as the Tug program develops. The SRA establishes criteria for design and provides data necessary to control those aspects of design and development that reduce support costs. A well planned and administered SRA will yield:

1) those functions in the Tug ground operations flow that require logistic support;

2) impact of ground operations on the design of Tug and its support equipment;

3) personnel tasks, equipment interfaces, and job skills required to implement the ground operations flow;

4) necessary training and technical documentation required to perform ground oerational tasks;

5) spares, support equipment, consumables, and facility requirements necessary for accomplishment of the ground operations flow;

6) Optimization of support elements as the Tug program matures.

4.5.1 Maintenance and Refurbishment Planning and Control -

The Tug contractor's Maintenance Engineering Analysis, as an element of Support Requirements Analysis, will establish early planning factors in terms of identified maintenance tasks, task times, facility interfaces, personnel skill levels, tools and support equipment, and commonality of resources necessary to the maintenace function. Levels and location of maintenance, reparable/nonreparable status, repair locations, and necessary supply categories (spares, bulk items, consumables) will be established. The analysis will be performed using the basic maintenance concepts - principally remove and replace to the LRU level established by NASA documentation and directive. The maintenance analysis must exercise broad latitude, within the confines of established policy, in determining the maintenance program most suitable to Tug and most cost effective in terms of overall program objectives. Table III-B-7 presents a summary of considerations for Level I, II, and III maintenance concepts that our study indicates most applicable to Tug.

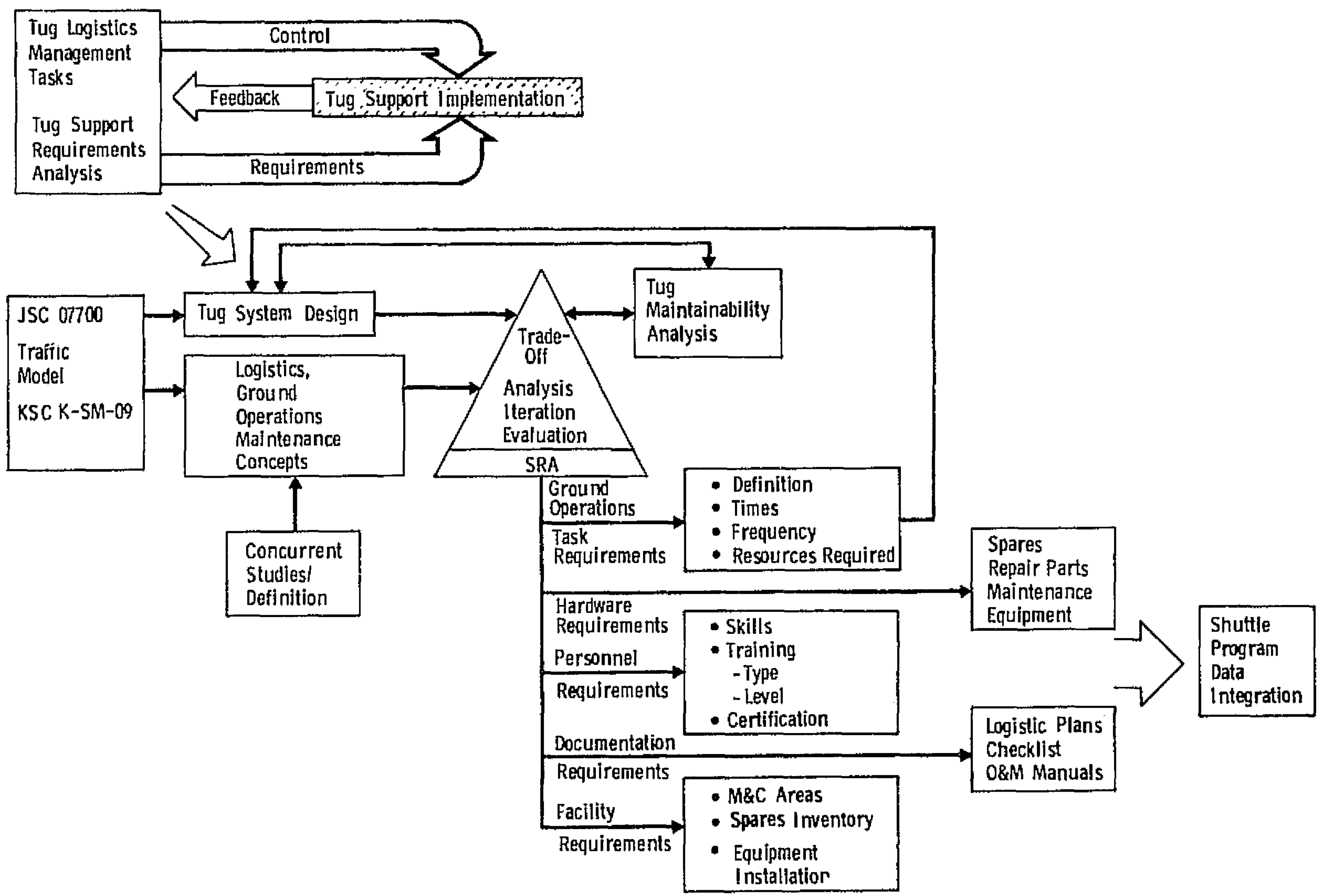

Figure III-B-39 Support Requirement Analysis

Table III-B-7 Tug Maintenance Concepts

Level I	Level II	Level III
Will include scheduled and unscheduled inspections, servicing, malfunction isolation, removal, replacement, verification, and subsystem checkout. Will normally be performed at the TPF. Will include vehicle and support equipment. Will provide for replacement at highest practical assembly level (LRU) based on: - Scheduled intervals for time or cycle sensitive items - Condition monitored item replaced due to indicated degradation/failure Malfunction to be assessed by onboard performance monitor system, maintenance display augmented by ground display and control. Will be predicted on post-flight maintenance activity plan and work package. Minimum scheduled maintenance planned.	Offline maintenance activities in support of Level I maintenance. Supports failure verification and minor LRU repair. Will include servicing, calibration, alignment rebuild and verification. Will normally be performed at KSC repair shops unless capability exists only at Tug manufacturer or supplier. Will rely heavily on installation of Shop Replaceable Units (SRUs). Optimum Repair Level Analysis (ORLA) may be used to help define repair activity.	Offline maintenance activities in support of Level I and II maintenance. Will include repair, overhaul, reverification of LRUs and SRUs. Provides capability for detailed failure analysis. Will be performed at Tug contractor or supplier during manufacturing cycle and at NASA/Air Force depots thereafter. Will provide for traveling technical team assistance from manufacturer/supplier to KSC.

Based on a coordinated set of maintenance concepts and the results of the maintenance engineering analysis, NASA should develop a Tug program Operational Maintenance/Refurbishment Plan as the controlling document for all maintenance activity. The results of the planning activity would be embodied in the plan in terms of Tug maintenance approach, maintenance tasks by subsystem and component, task sequences and flow for nominal and offnominal operations, personnel skill levels required, references to the applicable maintenance and repair sections of O&M manuals or OMIs, tools and equipment for specific tasks, and other resources necessary to the maintenance function.

NASA's control functions will require provisions for fleet and individual Tug maintenance status reporting, maintenance planning update and revision, spares provisioning and reorder, and reassessment/assignment of maintenance task times. Propellant and pressurant forecasts will have to be developed. Modification kits, based on the engineering change process, will have to be scheduled for installation at KSC with minimum impact on the turnaround timeline. Of paramount importance will be the Fleet Manager's involvement in preparation and scheduling of the Tug Post Flight Maintenance Activity Plan, which requires onsite involvement as part of the maintenance team at KSC.

Shelf life and installed life component tracking will be a logistics function to assure cyclic changeout of equipment as required. The agency responsible for spares provisioning and replenishment should plan to provide representation to the MRB.

4.5.2 Spares Acquisition and Management

4.5.2.1 Concepts for the Tug Program - The maintenance concept of remove and replace at the LRU level implies a large inventory of spares. New state of the art in areas like the airborne electronically steerable microwave phased array, the television system, and the scanning laser radar system plus turnaround times and allowable downtime precipitates decisions for insurance spares. Delayed procurement of spares will be a necessity based on probability of design change, anticipated high cost items, and the desired experience factor in new technology areas. These and other considerations highlight the need for a strong and comprehensive spares management program.

The following spares concepts are recommended for the Tug Program based on analysis of the Tug ground operations flow, the baseline Tug configuration definition, the KSC Shuttle System Ground Operations Plan, and the Space Shuttle Program Integrated Logistics Requirements, JSC 07700, Vol XII, Rev A.

1) The Tug contractor's SRA should be used to further define and refine initial spares requirements established by the Ground Operations Study.

2) Required Spare Parts Lists (RSPLs) should be generated by the Tug conctractor and delivered to NASA.

3) The Tug contractor should supply all replacement parts necessary to support the production cycle and any manufacturing testing.

4) The project should provide all spares for operational activities at the launch site based on contractor's RSPL.

5) Maximum use should be made of production items to satisfy initial spares requirements.

6) Only critical spares should be maintained at KSC during initial operational phase to reduce inventory control. Other spares should be shipped from production inventory on a kit basis.

7) Major provisioning of spares should be performed for KSC before the end of Tug production.

8) Level I and II spares should be located at ETR launch site. Level III spares should be located at NASA Depot after production cycle.

9) Failed components should be overhauled at Depot or supplier's facility.

10) KSC should supply spares to WTR. Only minimal levels of critical spares will be stocked at WTR consistent with CTMCF.

11) NASA should manage spares at KSC using a mechanized system.

4.5.2.2 *Spares Identification* - Figure III-B-40 presents a Tug spares approach starting with the RSPL action and culminating in disposition of repairables. Preliminary assessment of spares required for the Tug systems has been documented on the Maintenance Requirements Data Sheets supplied as Appendix E. Spare quantities were established principally at the ship set level during this initial analysis. Under our recommended approach the Tug contractor's SRA will review maintenance tasks, level, and location of maintenance, optimum repair levels, and refine the spares requirements culminating in development of RSPL that will document the spares for NASA provisioning purposes. The RSPL will be a line listing of recommended spares with budgetary estimated prices and should include all data elements required by NASA provisioning procedure for Tug. Spares should be identified as supporting Level I, II, or III maintenance activity.

4.5.2.3 *Spares Selection* - The spares selection process, illustrated in Figure III-B-41, should determine quantity, need date and allocation requirements. Based on these requirements, decisions will be made by NASA and the Tug contractor on each spare candidate to establish the most cost effective and efficient means of providing the spare.

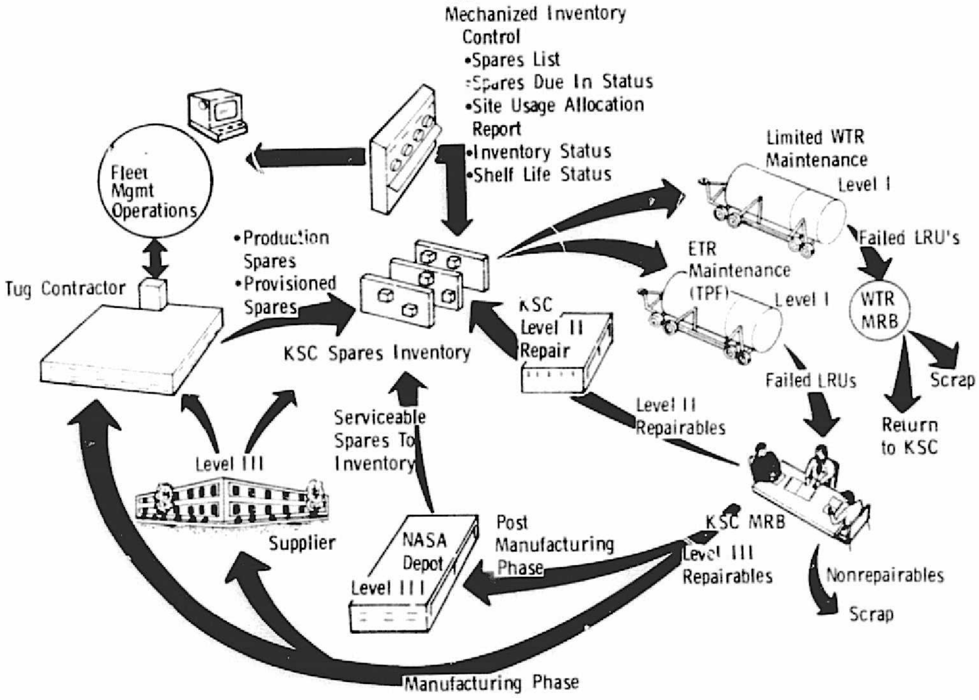

Figure III-B-40 Tug Spares Approach

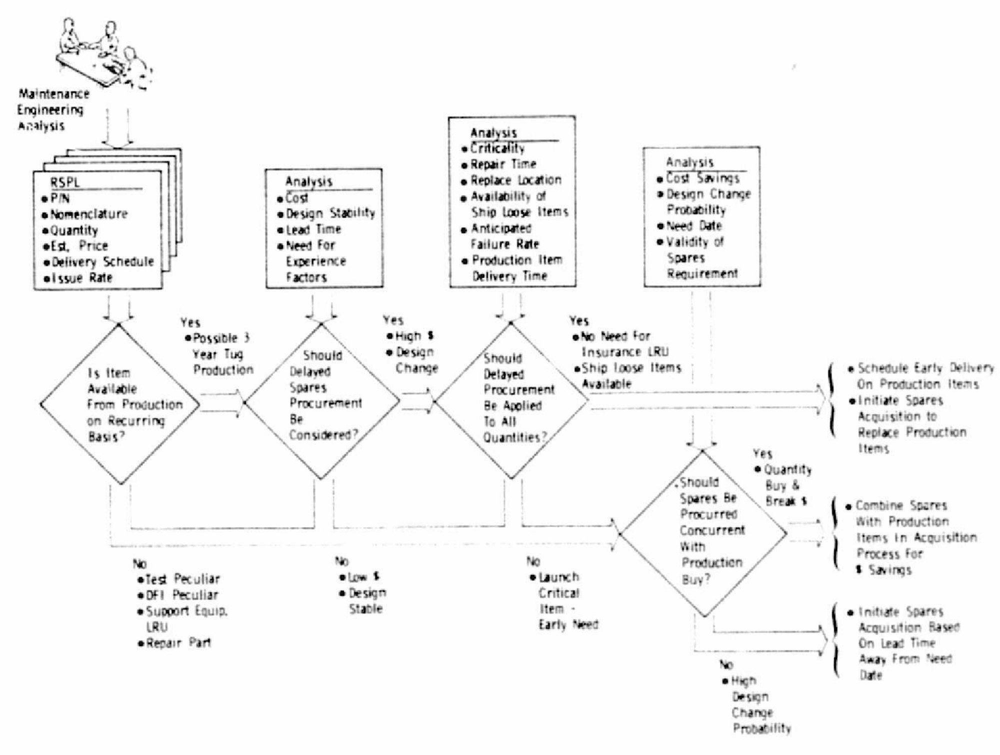

Figure III-B-41
Delayed Spares Procurement Decisions ..:q and Support Equipment

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Availability of the spare from production assets must be determined. The length of the Tug production cycle will be a determining factor on the extent of production item sparing that can be accomplished. If the spare is available from production assets on a recurring basis, dealyed procurement of the spare should be considered. If not, delayed procurement is not feasible and a decision should be made for concurrent buy of both production parts and spares to achieve quantity buy price break. Probability of design change before first spares usage must be weighted against cost savings.

Delayed procurement is most beneficial on high cost spares where a quantity decision involving only one unit is significant to program cost. Design change cost is minimized by having fewer spares on hand requiring modification. Delayed procurement defers the expenditure of spares money until experience factors can be obtained. If delayed procurement is determined, the decision must be made whether all or part of the initial spares requirement will be deferred. If delayed procurement is not feasible, concurrent buy of production parts and spares is again an option.

All or part of the spares may be identified for delayed procurement. If critical spares must be stocked at KSC, a portion of the required quantity should be spared and the remainder considered for delayed procurement. Decision factors will include failure rates, lead time to replace, and repair turnaround.

When quantity buy price can be obtained, concurrent buy should be initiated. The trade analysis will have to be made between probability of design change and estimated cost savings.

4.5.2.4 Spares Management - Based on the decision of the selection process, NASA will provision spares for KSC Level I and II activities and for Depot operations. If space permits, Level I critical spares should be maintained at the TPF to support Tug maintenance. Level II spares can be maintained at the KSC repair shops. Level III spares will be maintained at the Depot. NASA KSC should be responsible for warehousing and inventory control of provisioned spares, using a computerized inventory management and spares statusing. A Tug Logistics Resource Monitoring and Inventory Control Program will have to be developed. This system would contain as the minimum a spares list, spares due in status, spares site usage and allocation and spares inventory status. The Tug contractor would prepare the initial input data to this program governed by existing capability and format of the mechanized system.

When a spare is required for Tug maintenance operations at KSC, it should be drawn from the Level I and II inventory. If a provisioned spare is not available, a production spare should be drawn from the Tug contractor or supplier. Spares required for limited maintenance activities at WTR should be drawn from the KSC central inventory. This does not preclude minimal sparing of critical items at WTR to support damage incurred in transport or system health checks performed at WTR. A failed LRU will be dispositioned by the MRB at either KSC or WTR. Nonrepairables will be scrapped and replaced through appropriate contractor procurement or NASA provisioning action. Level II repairable items will be repaired at KSC repair shops. Level III items will be returned to the Tug manufacturer, supplier, or NASA Depot depending on the time phase of the production cycle. Repaired items will be retested, certified, and returned to either the TPF or Depot spares inventory.

Warehousing and inventory control management of spares will be established and maintained to support test and maintenance activities at KSC and WTR. The initial stock of spares, primarily LRU items, will be resupplied and resized on the basis of verified usage through the LPS or other mechanized system. Configuration control of spares will be maintained through the engineering change control system.

4.5.3 Operational Technical Documentation - Identification of the Operational Technical Documentation (OTD) requirements illustrated in Figure III-B-42 for Tug ground operations will begin with the Tug contractor's SRA. Review of the support requirements will yield the type, content, depth, and format of the OTD appropriate for Tug. The contractor will also be developing engineering, manufacturing process, test and checkout procedures, movement and shipping procedures that will provide much of the data needed for Tug OTD. OTD initial development requires coordination with design engineering and accessibility to specifications, technical reports, and manufacturing test reports.

KSC has identified the documentation structure and depth intended for use during Shuttle ground operations (Shuttle System Ground Operations Plan, K-SM-09). The assumption has been made for this study that MSFC, as the Tug development center, will require the Tug contractor to develop the documentation base for the Preliminary Configuration Manuals which MSFC will deliver to KSC. Because of his development responsibilities, the Tug contractor can most economically assist MSFC in defining and developing Tug OTD.

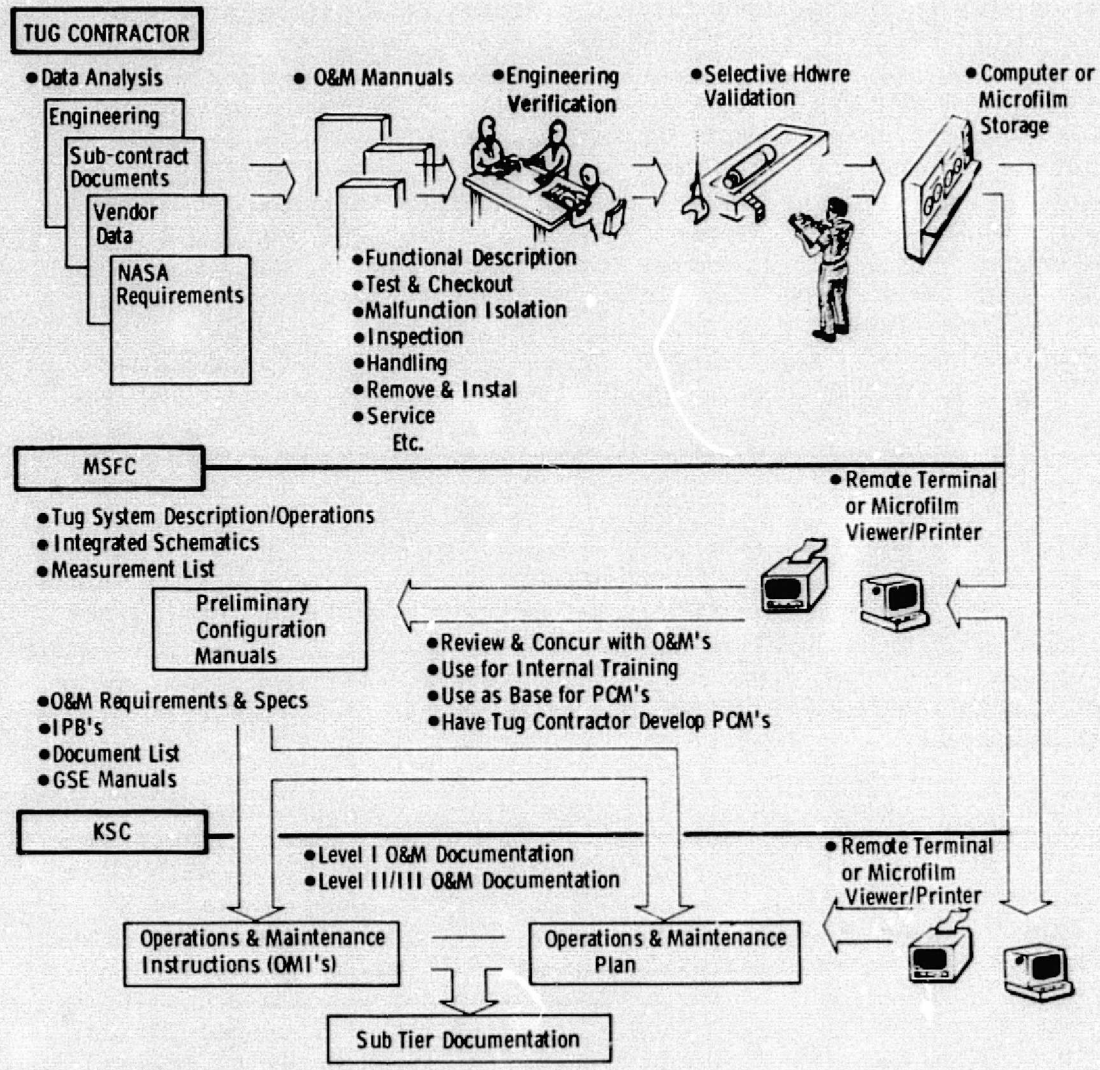


Figure III-B-42 Tug Operational Technical Documentation

Operations and Maintenance Manuals (O&M Manuals) will be developed for the overall Tug and for each subsystem as well as for contractor furnished GSE. Tug O&M Manuals will cover functional description; theory of operation; system interface requirements; maintenance procedure including trouble analysis and malfunction isolation, servicing, removal and installation; alignment and adjustment; necessary diagrams and schematics; handling, packaging, preservation, and storage requirements; and parts and components listing including spares and limited life components. GSE manuals will contain detailed operational and maintenance instructions and will include equipment description, operation, failure analysis and fault isolation, servicing, alignment, adjustment, cleaning, repair, test and inspection, and overhaul instructions.

O&M data developed by the Tug contractor would be prepared in the most cost effective manner consistent with NASA required format, specifically the KSC O&M Technical Documentation Plan. Training personnel can most efficiently develop these data. Data would be subjected to engineering review for accuracy and adequacy of equipment description, operating description, configuration, and supporting diagrams and schematics. Selective validation of engineering verified O&Ms would be accomplished on Tug hardware before final development and transmittal to NASA. O&Ms would be stored in a computerized data bank to permit economical and rapid retrieval for utilization, update, and NASA distribution. Hard copy could be obtained at the contractor's facility, reproduced, and shipped to NASA or a remote terminal system could be established for call-up and display at a NASA center depending on timeline requirements. A remote terminal system, which would permit addressing the O&M data bank from a using site, would enhance the documentation change cycle. O&M storage could also be accomplished by processing data on microfiche for storage, transmitting to using sites, and using viewers, and printers onsite. O&M indices would be produced for either method of storage and transmittal and provide NASA facility in selection and recall.

NASA will review, concur, or request change to the O&Ms produced by the contractor. The data should be used to support any classroom or video training conducted by NASA or by the contractor in order to reduce the cost of training support documentation. NASA will elect to use the contractor's O&Ms as a base for their own development of Preliminary Configuration Manuals or they will require the Tug contractor to develop the PCMs to NASA requested format. If NASA develops all or a portion of the PCMs for Tug, the concept of remote terminal display or microfiche printout of the contractor's data bank at a NASA center is most desirable and economically justified. Other contractor data and supplier data could also be transmitted as base input to PCMs at NASA or as input to OMIs and subtier documentation being developed at other NASA center.

In this program, as in past programs, maximum use will be made of the contractor's data required for his own manufacturing, test, and delivery operations and that he can most appropriately produce the system, subsystem, and component data required for ground operations functions.

4.5.4 Tug Training - MSFC will manage Tug training for its fleet management personnel who will require both planning and operational phase instruction on the Tug itself and the varied aspects of its management support. It is assumed that KSC will have the prime responsibility to train ground crews to handle, checkout, maintain, and service the Tug. Air Force personnel will require Tug training to support their operational program during IUS/Tug transition and Tug operational phases. Ground operations training requirements will include Tug familiarization; Tug system and subsystem description and operation including component location and accessibility; maintenance operations and techniques; GSE description, usage, maintenance, and checkout procedures; Tug handling and safety; and facility description and interface requirements. Figure III-B-43 illustrates the training process.

Cost effectiveness demands that maximum use be made of the Tug contractor's training program to satisfy NASA and Air Force requirements. The contractor's personnel training program will encompass system familiarization for all levels of personnel; detailed subsystem and component training for specific manufacturing and manufacturing test personnel; transportation, handling, and safety training; and skills training in areas like soldering, nondestructive testing and inspection, electrical connectors, and material processes. The contractor will train for unique processing manufacturing techniques peculiar to Tug or advanced state-of-the-art subsystems on Tug. When the contractor develops his training requirements analysis, he must also be cognizant of NASA and Air Force requirements for training so that commonality in training application can be affected wherever possible. Courses developed for contractor training should be formatted to also satisfy NASA/ Air Force requirements, especially in the Tug system/subsystem area and in those areas of manufacturing and process skills that would be required for onsite maintenance and repair.

The results of the contractor's training requirements analysis for Tug and for contractor developed GSE, as well as training plans, course outlines, and support material should be reviewed by NASA/Air Force for application to their needs. NASA/Air Force can elect to attend courses at the contractor's facility, bring courses to government facilities, or develop video tape instructional programs.

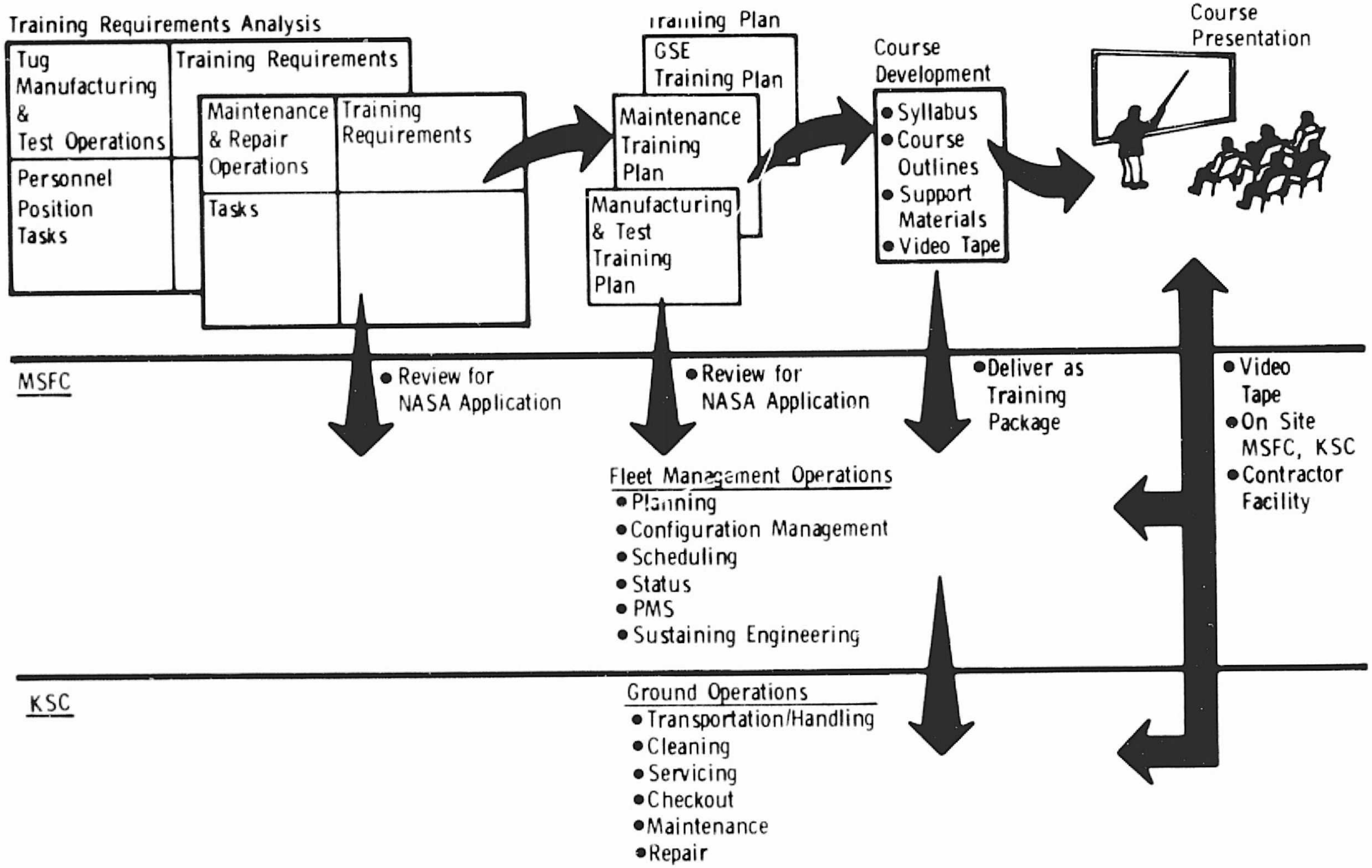


Figure III-B-43 Tug Training

It is usually more cost effective to bring instructors to NASA/Air Force facilities unless early availability of hardware at the contractor's facility materially enhances the training program. Video tape development by the contractor at familiarization or skills levels on systems not subject to a high degree of design change proved cost effective on Skylab. This technique permits training of NASA/Air Force personnel on a group or individual basis with least impact on working schedules.

A special concern should be shown for contractor developed training that stresses the interpretation of OFI as a maintenance prediction technique. A capability for presentation of programmed malfunction with fault isolation and corrective maintenance follow-through should be provided. With the high percentage of LRU activity anticipated, an OJT training capability should be provided for removal and replacement of those components that present unique requirements for handling or access.

NASA should develop, or contract for development, that training not covered by the Tug manufacturer, but necessary to fleet management operations. The current skill level and experience background of NASA personnel will determine the extent of this training.

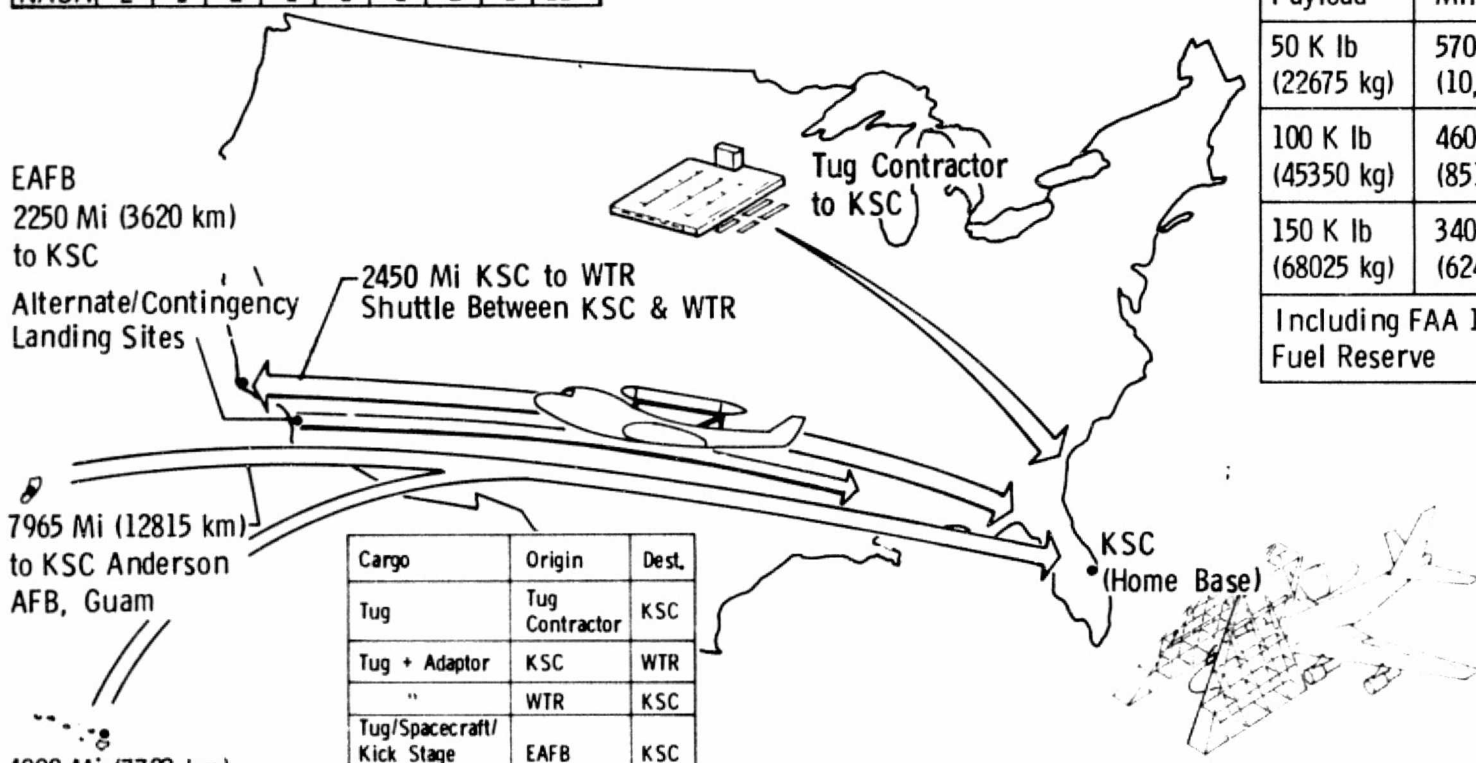
NASA should develop ground operations training for processing team personnel. Personnel can participate in contractor classroom training and video presentations for Tug system and subsystem as well as GSE training. Ground training that requires a high percentage of facility interface and KSC safety training should be developed by KSC with support from MSFC as required.

4.5.5 Transportation and Handling

4.5.5.1 Proposed Tug Ferry Operations - The study recommends that air transport be used to ship the Tug from manufacturer to KSC, between KSC and WTR, and to KSC from Orbiter alternative or contingency landing sites as shown in Figure III-B-44. Contractor shipments could extend over a three and one-half to four year production cycle based on a proposed fleet size of 12 to 15 Tugs. Currently planned NASA missions will require transportation support for 11 Tug flights at WTR between 1984 and 1991. Return of Tugs from alternative or contingency landing sites to KSC must be a real consideration for transportation planning over the life of the Shuttle program. Combined transport of Tugs and spacecraft between KSC and WTR, and the probability of combined return of Tug, spacecraft, and kick stages from alternative or contingency sites to KSC must be considered. Support equipment will require expeditious transfer between sites. The 14.66-foot (4.47 m) diameter of the Tug presents an outsized shipping configuration that precludes easy highway transport and water mode is not feasible based on turnaround times and probability of shipment from an inland manufacturer.

WTR Tug Flights									
	84	85	86	87	88	89	90	91	Total
NASA	2	1	2	1	1	1	2	1	11

747 Range	
Weight-Payload	Nautical Miles
50 K lb (22675 kg)	5700 NM (10, 556 km)
100 K lb (45350 kg)	4600 NM (8519 km)
150 K lb (68025 kg)	3400 NM (6246 km)
Including FAA 10% Fuel Reserve	



Cargo	Origin	Dest.
Tug	Tug Contractor	KSC
Tug + Adaptor	KSC	WTR
"	WTR	KSC
Tug/Spacecraft/ Kick Stage	EAFB	KSC
"	Hickam, Hawaii	KSC
"	Anderson, Guam	KSC
Support Equip.	All	All

Figure III-B-44 Transportation Requirements

Air transport will accomplish one day delivery from manufacturer to KSC or between KSC and WTR, and Tugs can be returned by air from alternative or contingency sites in minimal time.

The combined piggyback shipment of Tug within the Orbiter have been ruled out based on 747 loading factors and the negative scheduling aspects of shipping an Orbiter each time a Tug is shipped. The Tug would approach the maximum cargo envelope of the Pregnant and Mini Guppy aircraft and availability of the Super Guppy is questionable during the Tug operational time frame. A viable alternative is the piggyback shipment of Tug in a canister that occupies some portion of the envelope currently planned for piggyback shipment of the external tank. It is envisioned that this canister would be multiuse in nature, accommodating various payloads including Spacelab, as well as support equipment shipments, and affording maximum use of the canister as well as the 747 carrier aircraft. The envelope created by this 747 canister would accommodate Tug and spacecraft for combined payload shipments with maximum environmental protection and relative ease of handling. The canister would maintain clean conditions from the TPF throughout the transportation cycle. It would accommodate Tug, spacecraft, and kick stages for return from alternative or contingency landing sites. Based on an early availability of the canister, it could be used for IUS shipments although the Guppy aircraft and the C-5A could be used for that 10-foot (3 m) diameter load.

4.5.5.2 Ferry Operations Between KSC and WTR - The recommended transportation flow for ferry operations between KSC and WTR is depicted in Figure III-B-45. Considerations for alternative approaches are presented in Table III-B-8. The Tug will be prepared for piggyback shipment at the TPF while in its maintenance and checkout cell/stand. Tank blanket pressure is verified. Openings will be sealed and transportation flight instrumentation, recording devices, and the LH_2 tank forward dome cover will be installed. A prime mover will position a transporter with canister attached through the TPF airlock into the high bay aisle area to a point where it can receive the Tug. The canister will be a coffin-type cylinder split in half along its longitudinal axis. The top half of the cylinder will be removed by the TPF bridge crane and preparation for receipt of the Tug will be completed. The overhead bridge crane will be used to lift the Tug, move it to the canister, and position it in the canister. Tiedown attachments will be made to secure the Tug to the lower half of the canister. The upper half of the canister will be reinstalled and bolted at the canister attachment flanges. If facilities other than SAEF 1 are used as the TPF, adequacy of aisle space and facility of overhead cranes must be assessed to handle the canister loading. Tug will be processed vertically. A forward hoisting sling and aft pivot adapter will be used to obtain horizontal positioning. The Tug, secured inside the canister, will be towed by the prime mover from the TPF to the Shuttle airfield.

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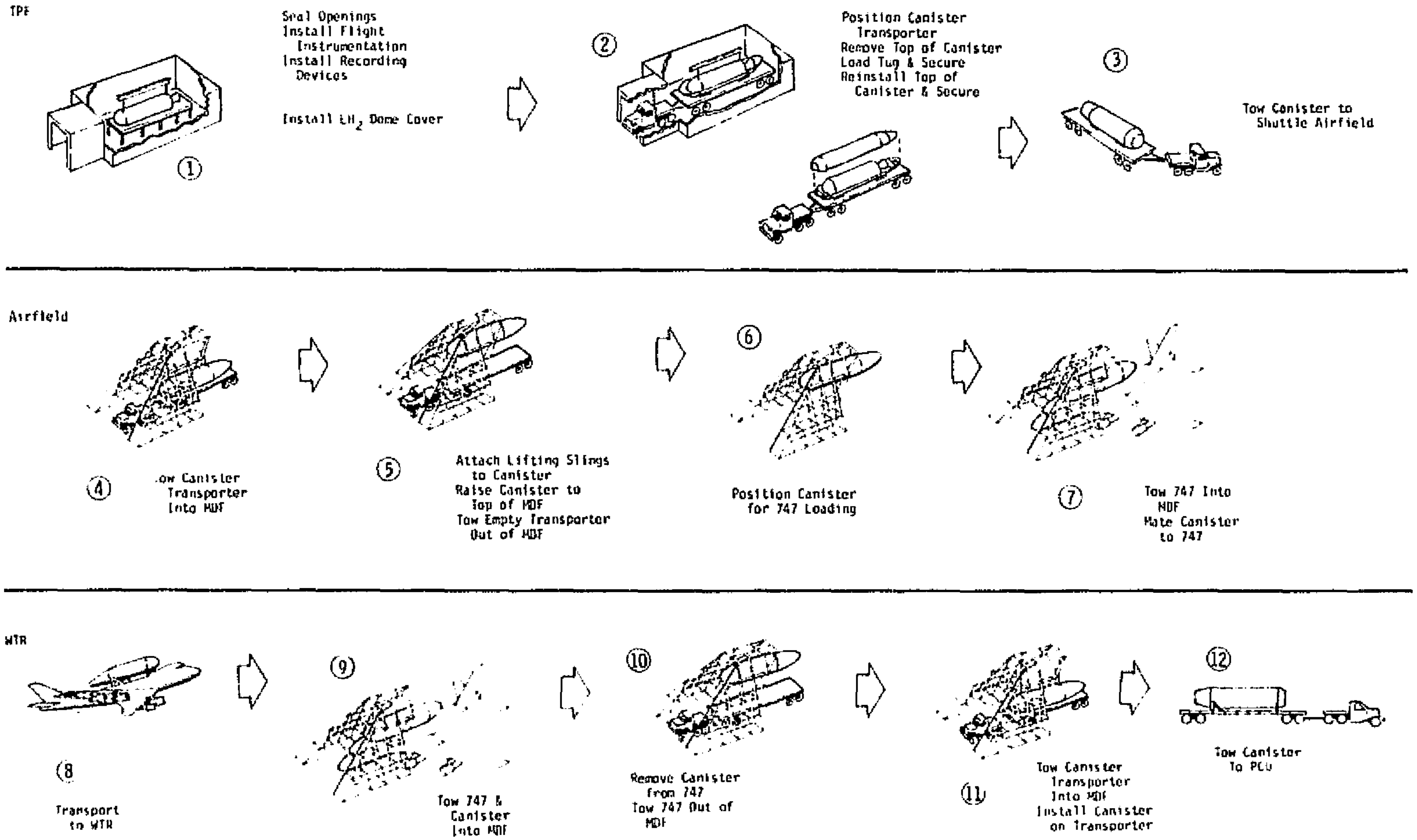

Figure III-B-45 KSC to WTR Transportation Flow

Table III-B-8 Alternative Transportation Approach Considerations

Function	Approaches	Considerations
Tug Transportation	Highway	Oversize configuration. Restricted travel times. Route survey required. Special routing. Permit acquisition. Escort, security control. Excessive time in transport.
	Rail	Oversize configuration. Unfavorable induced loads.
	Water	Probability of inland manufacturer. Excessive time in transport.
	Air	Cargo envelopes marginal for Pregnant and Mini Guppies. Availability of Super Guppy questionable. No other aircraft will accommodate. 747 piggyback is feasible - maximum use of aircraft.
Transfer to Tug from TPF to SHA	Load Tug on Transporter at TPF, Transfer to canister at SHA	Ease of access at TPF. Reduced handling at TPF. No requirement for dissassembly/reassembly of canister after leaving TPF. Reduced loading time at TPF.
	Load Tug into canister at TPF, Transfer Tug in canister to SHA	Reduced downstream handling - no requirement for later transfer to canister. Requires only one transporter - no second transporter or canister loading fixture at SHA. Maintains clean condition from TPF through transporter cycle. No requirement for environmental control at SHA.
Tug to Canister Transfer and Tie-down	Use Cylindrical Canister with End Doors	Requires rail or other translation system. Requires tow through or winching operation to load Tug. Requires cylinder beefup to control out-of-round. Increases access problems.

Table III-B-8 (concl)

Function	Approaches	Considerations
Tug to Canister Transfer and Tie-down (cont)	Use Coffin-Type canister with removable half sections.	Facilitates crane loading of Tug. Improves access for positioning and tiedown. Best approach to avoid structural degradation of canister.
	Place Tug on Transporter at TPF and Load Transporter with Tug into Canister (Roll On, Roll Off)	Assumes large canister approximating diameter of external tank. Requires ramp access to canister at SHA. Prime mover or winch operation required to load. Cylinderical canister with end door(s) required. Added weight of tranporter (8000 to 10,000 lb)
Lift and Install Canister on 747 Carrier Aircraft, Remove from Aircraft	Mobile Cranes and Access Stands or Lift Alofts	Two mobile cranes probably required. Increased size of ground crew - guide line, restraining line operations, etc. Operational safety. Aircraft access stands, personnel positioning devices required.
	Shared Use of Mate-Demate Fixture (MDF)	Maximum safety/security in handling operation. MDF is no cost to Tug if developed for Orbiter and available to Tug. Transfer capability to alternative contingency sites would reduce TSE requirement. Reduced time for KSC/WTR Tug loadings.

We recommend the use of the Mate-Demate Fixture (MDF), currently in design for Orbiter piggyback loadings at Palmdale and Edwards AFB, to lift and position the canister for attachment to the 747 aircraft. Multiple use of the MDF (Fig. III-B-46), is feasible and cost effective, and it is assumed the Palmdale and Edwards AFB fixtures can be broken down and reassigned to WTR and KSC, respectively, in time to support Tug operations in 1983.

Figure III-B-46
Mate-Demate Fixture (MDF)

When the canister transporter arrives at the Shuttle airfield from the TPF, it will be towed into the MDF. Forward and aft attachments will be made to the canister from the MDF cranes. The canister will be detached from its transporter and raised and positioned at the top of the MDF. The empty canister transporter will be towed out of the MDF. The 747 carrier aircraft will then be towed into the MDF and positioned beneath the canister. The canister will be lowered to its attach points with the 747 and attachment will be completed. The 747 with piggyback canister attached will be towed out of the the MDF and to the airstrip for taxi and takeoff.

After landing at WTR, the 747 will taxi to proximity of the MDF. After engine shutdown and postflight checks, the aircraft will be towed into the MDF. Crane attachments will be made, the canister will be disconnected and lifted free of the aircraft, and the aircraft will be towed out of the MDF. The canister transporter will be towed into position in the MDF. The canister will be lowered and attached to its transporter, which will be towed to the PPF.

4.5.5.3 Ferry Operations Between Tug Manufacturer and KSC - Further use of the 747 is recommended for Tug shipments from the manufacturer to KSC. A contractor loading operation would be similar to that described for KSC to WTR transport but would use a crane operation at the airfield instead of the MDF. A canister transporter, controlled and operated by the manufacturer and possibly a modification of their manufacturing dollies, would be towed to the nearest 747 airfield to meet an arriving carrier aircraft with canister attached. Mobile cranes would be used at the airfield in conjunction with Lift Alofts or similar personnel positioning devices to demate the canister, lift it from the carrier aircraft, and place it on the transporter. After canister to transporter attachment, the canister transporter would be towed to the manufacturing facilities. Loading of the Tug into the canister will be performed essentially as described for the TPF at KSC. After loading has been completed, the Tug within the canister will be towed to the

airfield for loading on the 747. The mobile cranes will lift the loaded canister from the transporter and position it on the aircraft for attachment. The transporter will be returned to the manufacturer's facility and the 747 will fly the Tug within the canister to KSC.

4.5.5.4 Ferry Operations Between Alternate/Contingency Sites and KSC - The 747 carrier aircraft will be used to return Tugs/spacecraft/kick stages from Edwards, Hickam, or Anderson AFBs in the event of alternate or contingency landing. The 747 with attached canister will be dispatched to return the Tug/spacecraft/kick stage after return of the Orbiter. Current KSC ground operations planning calls for disassembly, transfer, and reassembly of an MDF for Orbiter handling at alternative or contingency sites. We recommend the extended use of this fixture to handle the canister at alternative or contingency sites after it has been used to load the Orbiter. Air transfer of the MDF from WTR would be required to reserve the KSC MDF for 747 orbiter removal and canister installation at that site based on the assumption that only one 747 will be used.

After Orbiter landing and initial deactivation and securing, it will be towed to the safing and deservicing area at the alternative contingency site. Vent, drain, purge, and additional safing operations will be performed. When deservicing operations are completed, the payload will be removed by crane and placed on temporary storage dolly(s). Further Tug/spacecraft/kick stage securing operations and preparation for return shipment will be accomplished. When the 747 arrives with a canister, after Orbiter return, the MDF will be used to remove the canister and place it on a canister transporter. The canister will be towed to the Tug/spacecraft/kick stage area where loading operations will take place. The loaded canister will be towed to the MDF, which will lift and position it on the 747. Attachments will be completed and the 747 will return to KSC. The MDF will be disassembled and returned to WTR.

4.5.5.5 Transportation Management Operations - The Tug Project will be responsible for overall Tug fleet utilization and scheduling and will generate Tug transportation schedules, coordinate with JSC for use of the 747 carrier aircraft, and coordinate with KSC/WTR transportation branches and designated operational support contractors for receipt, handling, and shipping operations. Priority scheduling will be required for use of the 747s, which will also be ferrying Orbiter and External Tanks. Status and schedule of TSE for Tug transportation operations is envisioned as a joint responsibility between MSFC, KSC, and USAF.

Initial shipments of the Tug from the manufacturer to KSC will be the responsibility of the Tug contractor under the guidance and direction of MSFC who will coordinate receipt and handling with the KSC transportation branch and/or designated KSC organizational

element and operational support contractor. MSFC will schedule and coordinate ferry operations between KSC and WTR as well as return ferry flights from alternative/contingency sites.

Because of priority scheduling requirements for the 747, overlap of manufacturer's deliveries, and operational transfers to WTR, and the probability of contingency/alternative site return transportation, a computerized transportation scheduling segment for a Tug Fleet Utilization Planning System is recommended. Computer simulation can be used to establish the transportation support requirements for a given set of alternative or contingency landing factors to establish preplanning for efficient return of Tug/spacecraft/payloads from alternative/contingency sites. Unpredicted downtime of aircraft, failure or unavailability of shared TSE like the MDF, weather conditions, etc, could be factored into the Transportation Scheduling Segment of the Planning System for a best-decision approach to Tug transportation scheduling.

Detailed transportability/transportation analysis should be developed by the Tug contractor for review and approval by MSFC and the KSC/WTR transportation branches and/or designated organizational elements. Transportation plans should be developed for each major requirement such as shipment from manufacturer to KSC, ferry service between KSC and WTR, and return shipments from alternative and contingency landing sites to KSC. Individual delivery plans should be developed as required by specific Tug shipments to implement the overall transportation plans. Delivery plans should include sequence charts and detailed transportation and handling procedures. O&M manuals will contain procedures necessary to operate and maintain the TSE.

5.0 Contingency Analysis

Several contingencies can occur during the operational life of the Tug system. Preparation for these contengencies must be made in advance of the detail design, otherwise serious consequences on the timely launching of Tugs to satisfy mission requirements might result. The purpose of this analysis is to (1) identify those contingencies, and (2) provide advance planning to minimize the affect of such contingencies.

5.1 Identify Contingencies

The contingencies that can occur include hardware and software failures (no-go), hardware and software delivery problems (no-show) and programmatic changes (schedule change, priority payload). Figures III-B-47, III-B-48, and III-B-49 generically identify the alternatives that are available if the contingencies do occur. These figures serve as a road map that leads to the identification of possible alternatives for specific contingencies in the Tug system.

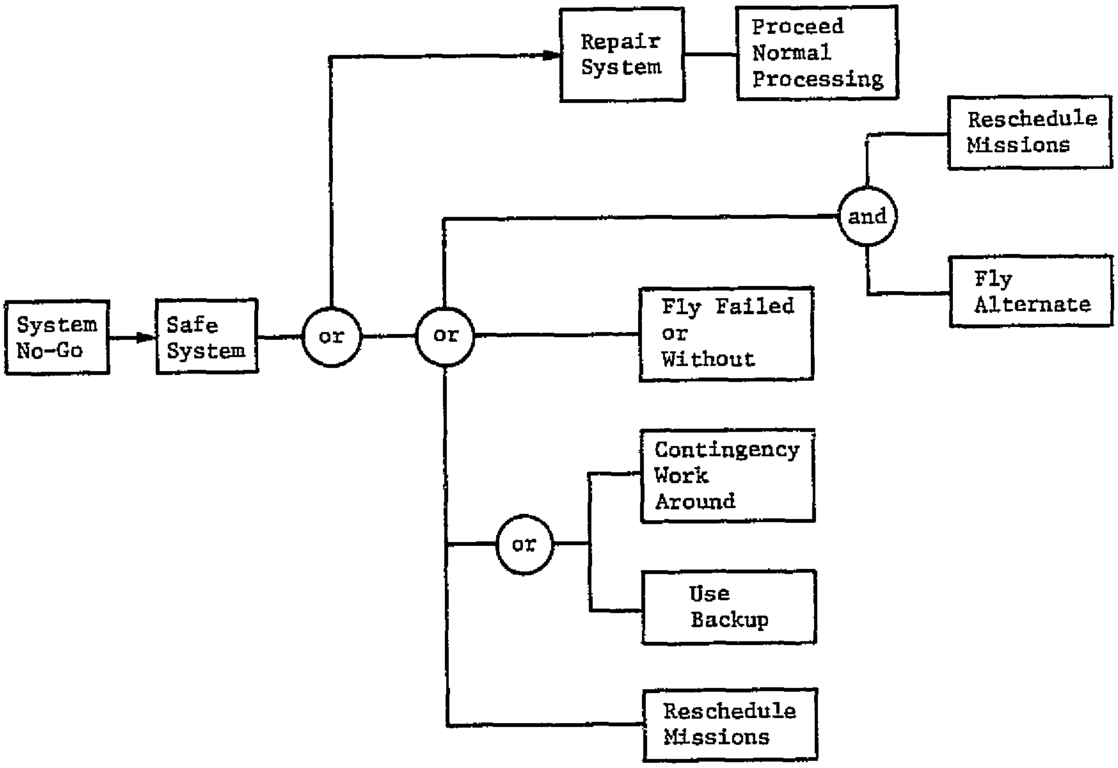

Figure III-B-47 System No-Go Alternatives

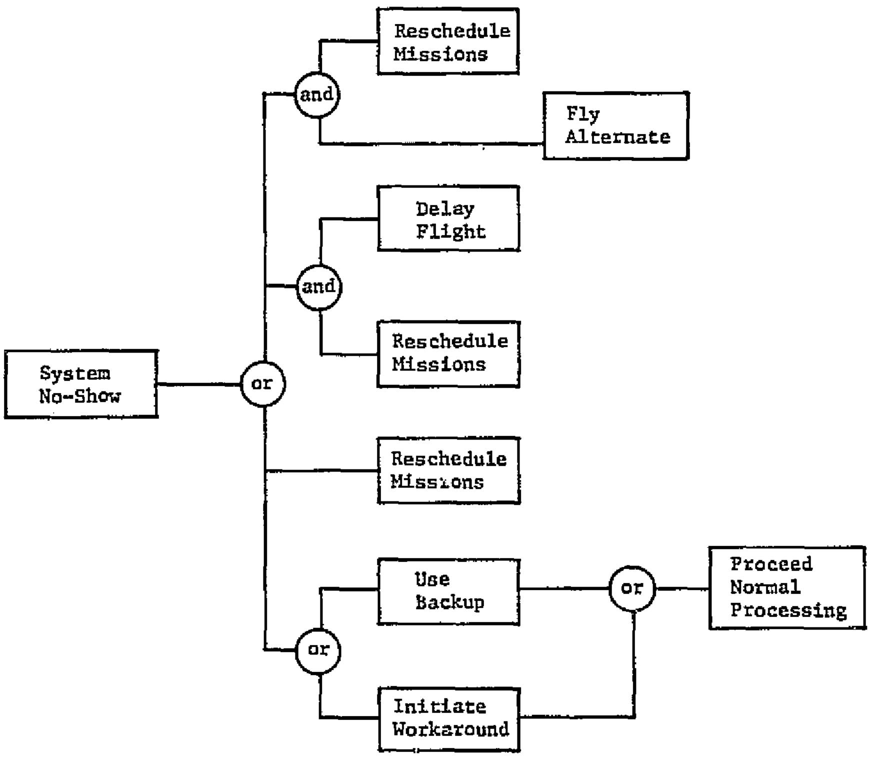

Figure III-B-48 System No-Show Alternatives

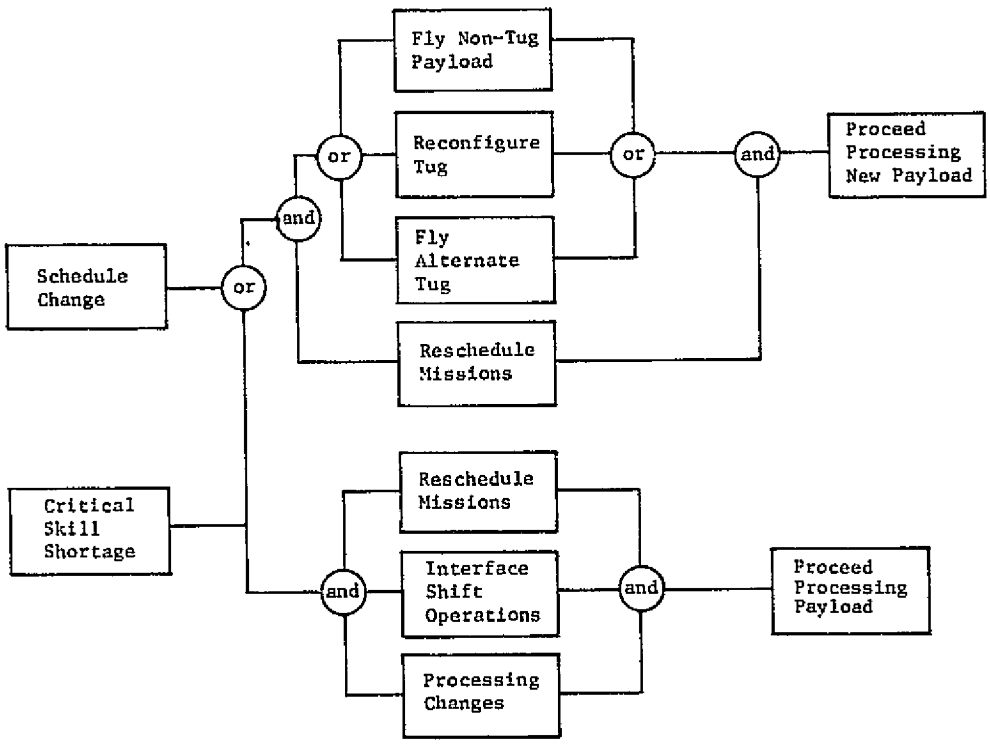

Figure III-B-49 System Programmatic Change Alternatives

Specific contingencies have been postulated on a "what if" basis for different time frames of the Tug ground processing flow of subplan A. Table III-B-9 summarizes these contingencies and enumerates potential alternatives that could be employed in each case.

5.2 Identify Selective Contingency Provisions for Planning Purposes

Perusal of Table III-B-9 leads to several selective provisions that should be implemented in the system now to minimize the effect of contingencies. These provisions range all the way from system design criteria to backup hardware/software, and the recommended provisions have been itemized and summarized in para 3.1 of this subplan.

Table III-B-9 Contingency vs Potential Impact

Potential Impact / Contingency Situation	Impacts Shown with Respect to Ground Processing Phases					Remarks
	Refurbish and Checkout	Tug/Spacecraft Mate and Checkout	Tug/Spacecraft /Orbiter Mate and Checkout	Launch Operations	Post Landing Operations	
Spacecraft No-Go	Repair spacecraft Increase work shifts Fly buffer spacecraft Reschedule mission	Repair spacecraft Fly buffer spacecraft Fly mass simulator Increase work shifts	Repair spacecraft Fly buffer spacecraft Fly mass simulator Fly degraded spacecraft Reschedule missions	Fly buffer spacecraft Fly mass simulator Fly degraded spacecraft Reschedule missions	N/A	Flying a degraded spacecraft involves a real time decision, e.g., one of several experiments malfunctions
Spacecraft No-Go (Emergency)	Safe spacecraft then proceed as above	Safe spacecraft then proceed as above	Safe spacecraft then proceed as above	Safe spacecraft then proceed as above	Safe spacecraft then continue normal operations	
Spacecraft No-Show	Delay flight Fly buffer spacecraft Fly mass simulator Reschedule missions	Fly buffer spacecraft Fly mass simulator Reschedule missions	N/A	N/A	N/A	A buffer spacecraft will minimize this impact
Priority Spacecraft No-Go	Repair spacecraft	Repair spacecraft	Repair spacecraft Reschedule missions	Repair spacecraft Reschedule missions	N/A	
Tug/IUS No-Go	Repair Tug/IUS Increase work shifts Fly alternative Tug/IUS	Repair Tug/IUS Increase work shifts Fly alternative Tug/IUS Fly non-Tug payload Reschedule missions	Repair Tug/IUS Fly alternative Tug/IUS Fly non-Tug payload Reschedule missions	Fly alternative Tug/IUS Fly non-Tug payload Reschedule missions	N/A	A backup Tug would alleviate this contingency
Tug/IUS No-Go (Emergency)	Safe Tug/IUS then repair Tug/IUS	Safe Tug/IUS then proceed as above	Safe Tug/IUS then proceed as above	Safe Tug/IUS then proceed as above	Safe Tug/IUS then continue normal operations	
Tug/IUS No-Show	Fly alternative Tug/IUS Delay flight Fly non-Tug payload Reschedule missions	Fly alternative Tug/IUS Delay flight Fly non-Tug payload Reschedule missions	N/A	N/A	N/A	A backup Tug would eliminate this contingency
Kick Stage No-Go	Repair kick stage	Repair kick stage Replace kick stage Fly buffer spacecraft Reschedule missions	Repair kick stage Replace kick stage Fly buffer spacecraft Reschedule missions	Fly buffer spacecraft Reschedule	N/A	A backup kick stage will alleviate this contingency.

Table III-B-9 (cont)

Potential Impact / Contingency Situation	Impacts Shown with Respect to Ground Processing Phases					Remarks
	Refurbish and Checkout	Tug/Spacecraft Mate and Checkout	Tug/Spacecraft /Orbiter Mate and Checkout	Launch Operations	Post Landing Operations	
Kick Stage No-Go (Emergency)	Safe kick stage then proceed as above	Safe kick stage then proceed as above	Safe kick stage then proceed as above	Safe kick stage then proceed as above	N/A	
Kick stage No-Show	Delay flight Fly buffer spacecraft Reschedule missions	Fly buffer spacecraft Reschedule missions	N/A	N/A	N/A	A backup kick stage will eliminate this contingency
Shuttle No-Go	Proceed normally	Proceed normally	Delay flight Reschedule missions	Delay flight Reschedule missions	N/A	
Shuttle No-Show	Proceed normally	Proceed normally	Delay flight Reschedule missions	Delay flight Reschedule missions	N/A	
Shuttle No-Go (Emergency)	Safe Shuttle Proceed normally	Safe Shuttle Proceed normally	Safe Shuttle Delay flight Reschedule missions	Safe Shuttle Delay flight Reschedule missions	Safe Shuttle Continue normal operations	
Tug (IUS) to Spacecraft Interface No-Go	N/A	Repair spacecraft or Tug (IUS) Fly alternate Tug (IUS) or buffer spacecraft Fly non-Tug payload Reschedule missions	Repair spacecraft or Tug (IUS) Fly alternate Tug (IUS) or buffer spacecraft Fly non-Tug payload Reschedule missions	Repair spacecraft or Tug (IUS) Fly alternate Tug (IUS) or buffer spacecraft Fly non-Tug payload Reschedule missions	Initiate emergency safing procedures	
Tug (IUS) to Orbiter Interface No-Go	N/A	N/A	Repair Tug (IUS) or Orbiter Fly alternative Tug (IUS) Reschedule missions	Repair Tug (IUS) or Orbiter Fly alternative Tug (IUS) Reschedule missions	Initiate emergency safing procedures	
Spacecraft to Spacecraft Interface No-Go (Multiples)	Repair interface	Repair interface Delete failed spacecraft Fly mass simulator	Repair interface Delete degraded spacecraft Fly mass simulator	Repair interface Delete degraded spacecraft Fly failed spacecraft Fly mass simulator	N/A	

Table III-B-9 (cont)

Potential Impact / Contingency Situation	Impacts Shown with Respect to Ground Processing Phases					Remarks
	Refurbish and Checkout	Tug/Spacecraft Mate and Checkout	Tug/Spacecraft /Orbiter Mate and Checkout	Launch Operations	Post Landing Operations	
Facility 100,000 Clean No-Go – TPF	N/A	Repair facility Delay integration of Tug (IUS) and spacecraft Contingency cleaning	N/A	N/A	N/A	
– SPF	N/A	N/A	N/A	N/A	N/A	
– OPF	N/A	N/A	N/A	N/A	N/A	No Tug (IUS) or spacecraft requirement
– PCR	N/A	N/A	Delay flight Contingency cleaning	N/A	N/A	
Facility Storable Propellant System No-Go	N/A	Repair facility Manual loading of Tug APS and spacecraft	N/A	N/A	N/A	
Facility Pressurization System No-Go	Repair facility K-bottle backup	Repair facility K-bottle backup	Repair facility Delay flight Reschedule missions	Repair facility Delay flight Reschedule missions	K-bottle backup	Functional redundancy will alleviate this contingency
PCR No-Go	N/A	N/A	Repair PCR Schedule alternate launch site Reschedule missions	Repair PCR Reschedule missions	N/A	Two launch pads (and PCRs) help alleviate this contingency
Commodity No-Show	Reschedule missions	Reschedule missions	Reschedule missions	Reschedule missions	Contingency tank purge (e.g., N_2)	
Facility Cryogenic System No-Go	N/A	N/A	N/A	Delay flight Reschedule mission	N/A	Functional redundancy will alleviate
LPS No-Go	Repair LPS Delay Checkout Delay flight Reschedule missions	Repair LPS Delay integration Delay flight Reschedule missions	Repair LPS Delay integration Delay flight Reschedule missions	Repair LPS Delay flight Reschedule missions	N/A	Functional redundancy will alleviate
Payload Canister No-Go (or No-Show)	N/A	Obtain backup canisters	N/A	N/A	N/A	
Payload Manipulator No-Go	N/A	N/A	Repair manipulator Delay flight Schedule alternative launch site Reschedule missions	N/A	N/A	

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Table III-B-3 (cont)

Potential Impact / Contingency Situation	Impacts Shown with Respect to Ground Processing Phases: Refurbish and Checkout	Tug/Spacecraft Mate and Checkout	Tug/Spacecraft /Orbiter Mate and Checkout	Launch Operations	Post Landing Operations	Remarks
GSE No-Go	Repair GSE Use alternative GSE	Repair GSE Use alternative GSE	Repair GSE Use alternative GSE	N/A	Use alternative GSE Repair GSE	GSE end items generally not one of a kind Functional redundancy will alleviate
Spares No-Show	Delay checkout Rob alternative Tug (IUS) Reschedule mission	Delay checkout Rob alternative Tug (IUS) Reschedule mission	Delay checkout Rob alterna tive Tug (IUS) Reschedule mission	N/A	N/A	
Simulator No-Go	Repair simulator Delay checkout Extend checkout	Repair simulator Delay checkout Extend checkout	N/A	N/A	N/A	Flight article tests can replace simulators for time critical missions
Flight Abort	N/A	N/A	N/A	N/A	Dump Tug propellants Proceed normally	
Crash Landing	N/A	N/A	N/A	N/A	Initiate contingent Tug safing Reschedule missions	Tug not in flying condition after crash landing Backup Tug will alleviate this contingency
Software No-Go	Replace software Delay flight Reschedule missions	Replace software Delay flight Reschedule missions	Replace software Delay flight Reschedule missions	Replace software Delay flight Reschedule missions	Replace software Contingency Tug control after Orbiter separation	Redundancy will alleviate this contingency
Software No-Show	Defer Tug (IUS) Integration to PCR Delay flight Reschedule missions	Defer Tug (IUS) Integration to PCR Delay flight Reschedule missions	Delay flight Reschedule missions	N/A	N/A	Software is routine except the Tug (IUS) to spacecraft software interface
Schedule Change - Priority Spacecraft-Tug	Reconfigure Tug (IUS) Fly alternative Tug (IUS) Reschedule missions	Replace spacecraft Reconfigure Tug (IUS) Fly alternative Tug Reschedule missions	Replace spacecraft Replace spacecraft and Tug (IUS) Reschedule missions	Replace spacecraft Replace spacecraft and Tug (IUS) Reschedule missions	N/A	Contingency payload changeout Backup Tug will help alleviate this contingency
- Priority Payload - Non-Tug	N/A	N/A	Recycle Tug (IUS) and spacecraft Reschedule missions	Recycle Tug (IUS) and spacecraft Reschedule missions	N/A	Priority payload changeout

Table III-B-9 (concl)

Potential Impact / Contingency Situation	Impacts Shown with Respect to Ground Processing Phases					Remarks
	Refurbish and Checkout	Tug/Spacecraft Mate and Checkout	Tug/Spacecraft /Orbiter Mate and Checkout	Launch Operations	Post Landing Operations	
- Uneven Launch Centers	Increase shifts Delay check-out	Increase shifts Delay integration Reschedule missions	Increase shifts Delay integration Reschedule missions	Increase shifts Delay launches Reschedule	N/A	An additional Tug checkout cell will help alleviate this contingency
Critical Skill Shortage	Increase shifts Reschedule missions	Increase shifts Reschedule missions	Increase shifts Reschedule missions	Increase shifts Reschedule missions	Increase shifts	
Safety No-Go (Range, Weather)	N/A	N/A	N/A	Delay flight Reschedule missions		

CONTENTS

Figure

1.0 Introduction

Data presented in this subplan were derived from an analysis of the Tug ground operations processing flows generated in Task 1.0, and supplemented with appropriate information from the Program Development Space Tug Task Team. This plan identifies support and interface requirements for Shuttle payload accommodations during the mission planning era. The term payload as used here is the Tug with its deployment adapter and its spacecraft and/or kick stage.

Major IUS/Tug payload accommodation elements influenced by various utilization and operational considerations were analyzed to determine their impact on payload requirements. These elements included payload interface requirements, operational resource identification and allocation, handling and safety procedures, integrated testing and checkout requirements, simulation and/or interface verification requirements, and data requirements.

During this analysis, special emphasis was placed on the generation of a Tug user's planning guide outline to provide data essential for advance mission planning and spacecraft conceptual design. The outline is oriented to those areas of user interest and needs, in terms of Tug/Spacecraft hardware interfaces, environments, available services, mission capabilities, spacecraft integration, and an overview to familiarize new users with the Shuttle/Tug Space Transportation System.

2.0 General Requirements

The IUS/Tug payload integration includes necessary planning and preparation before hardware arrival at KSC, and all activities from arrival of the flight hardware and ground support equipment (GSE) through launch. This planning and preparation includes those activities for Tug/spacecraft mating and integrated checkout of the total payload element and integrated checkout with the Orbiter. Throughout the study, certain ground rules and guidelines were baselined and/or assumed to accomplish the required analysis.

2.1 Ground Rules

1) The spacecraft is flight ready when it is received for Tug/spacecraft integration.

2) Postflight removal of the Tug/spacecraft will be accomplished at the Orbiter processing facility (OPF).

3) No maintenance of the Tug/spacecraft will be performed while in the Orbiter bay.

4) Payload to Orbiter mate occurs on-pad, although we recognize an option to install horizontally in the OPF.

2.2 Guidelines

1) LPS is primary mode of Tug ground checkout.

2) Tug/spacecraft mating and handling will be accomplished in vertical position in a TPF test cell with option for vertical mating at payload changeout room (PCR).

3) Spacecraft will be handled and checked out vertically after mating with Tug.

4) Tug to spacecraft mate and checkout is performed off-pad.

5) Spacecraft to be mated to the Tug and checked out in 100K clean area.

3.0 Operational Phase Study Elements

The contract requires that 12 standard study elements be addressed in each subplan. To maintain standard numbering, paragraphs 3.1 through 3.12 of each subplan address those 12 elements, although not all elements are applicable to every subplan.

3.1 Ground Operations Flow

The overall Tug/spacecraft ground operations functional flow was developed in subplan A. Spacecraft mate through launch is described by function blocks 5.1 through 7.3 on the green light flow. For convenience , that segment of the flow is shown in Figure III-C-1 of this subplan.

The green light flow described spacecraft mating at the TPF; however, options are presented for spacecraft checkout at the Spacecraft Processing Facility or at the PCR. Upon mission completion, Tug/spacecraft ground operations are described by function blocks 1.1 and 1.2. To better understand the flow and interrelationships of certain hardware elements, we have included the entire Tug ground operations flow from subplan A in Figure III-C-2.

3.1.1 <u>Operations</u> - Although the baseline ground rule states that the spacecraft would be delivered to the TPF in a ready-to-mate condition, the unique integration and operations requirements of multiple payloads must be considered. One area of potential threat to the on-time green light Tug ground processing is the possibility of interface problems between multiple payloads. Payload to Orbiter interfaces are described in the Shuttle Payload Accommodations Document, JSC 07700. Interface verification impacts of individual elements in contrast to fully integrated payloads, as well as preferred multiple payload integration techniques, have not been identified. Unique launch site requirement levied by multiple

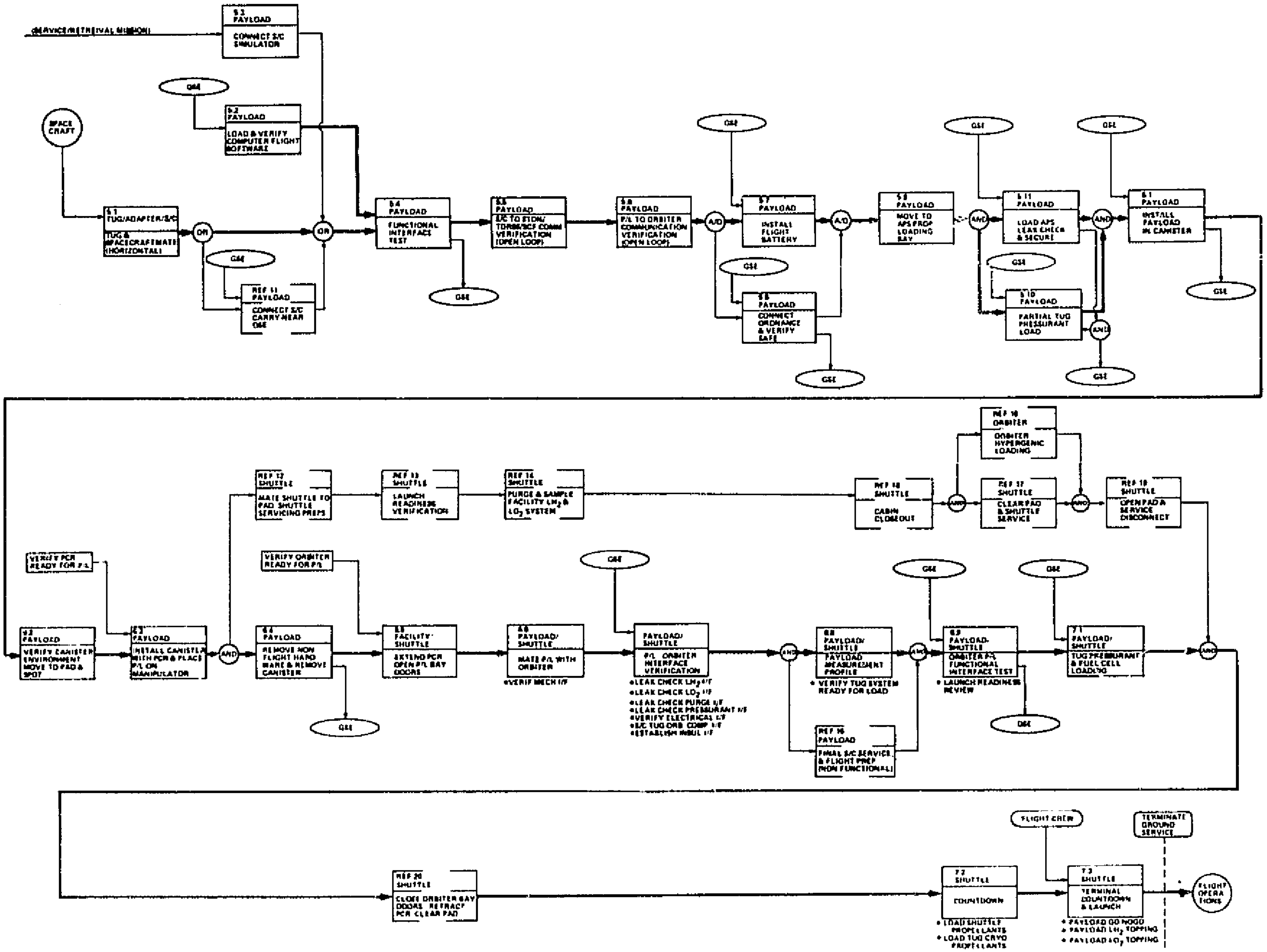

Figure III-C-1 Spacecraft Ground Operations Flow

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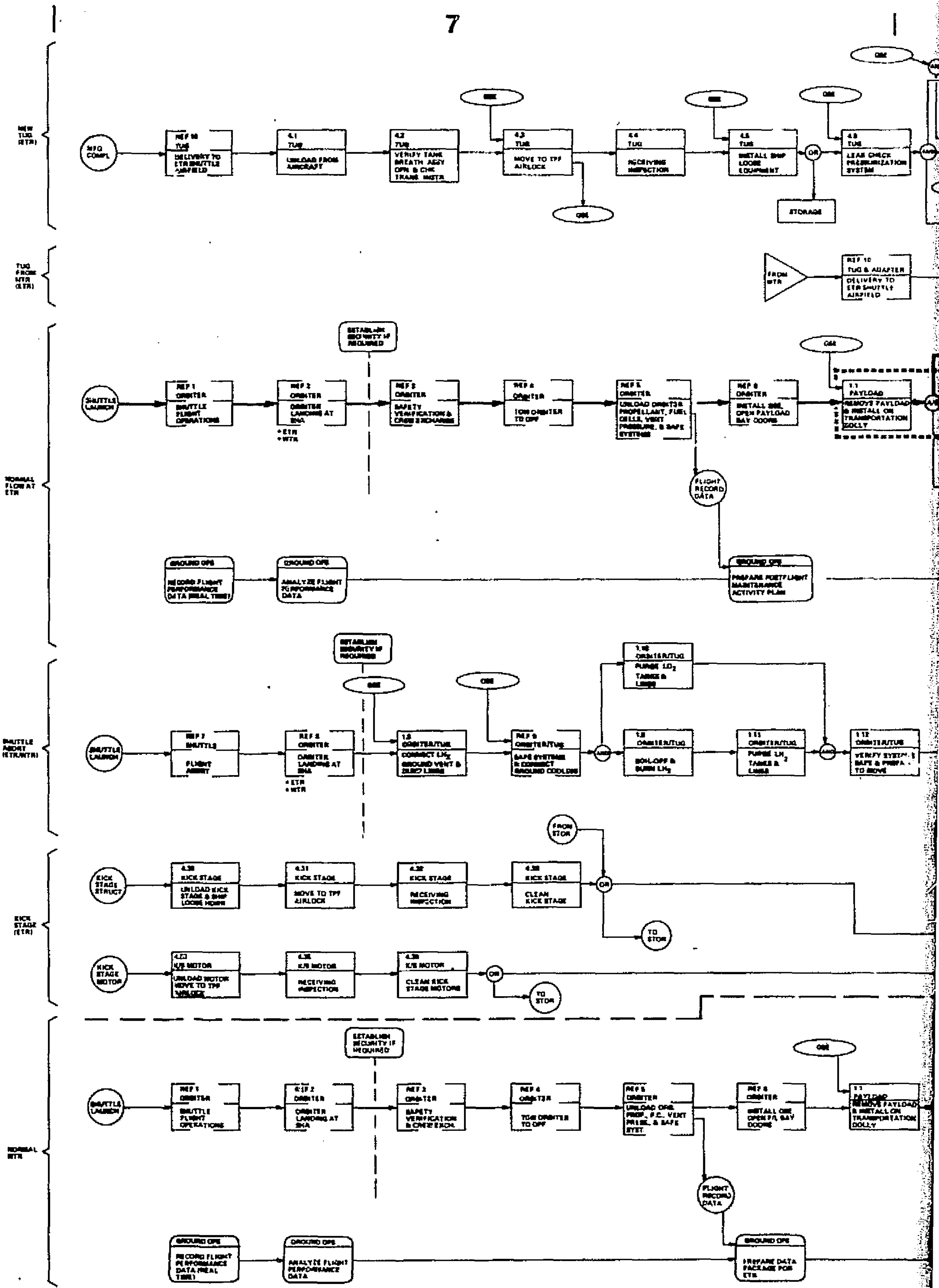

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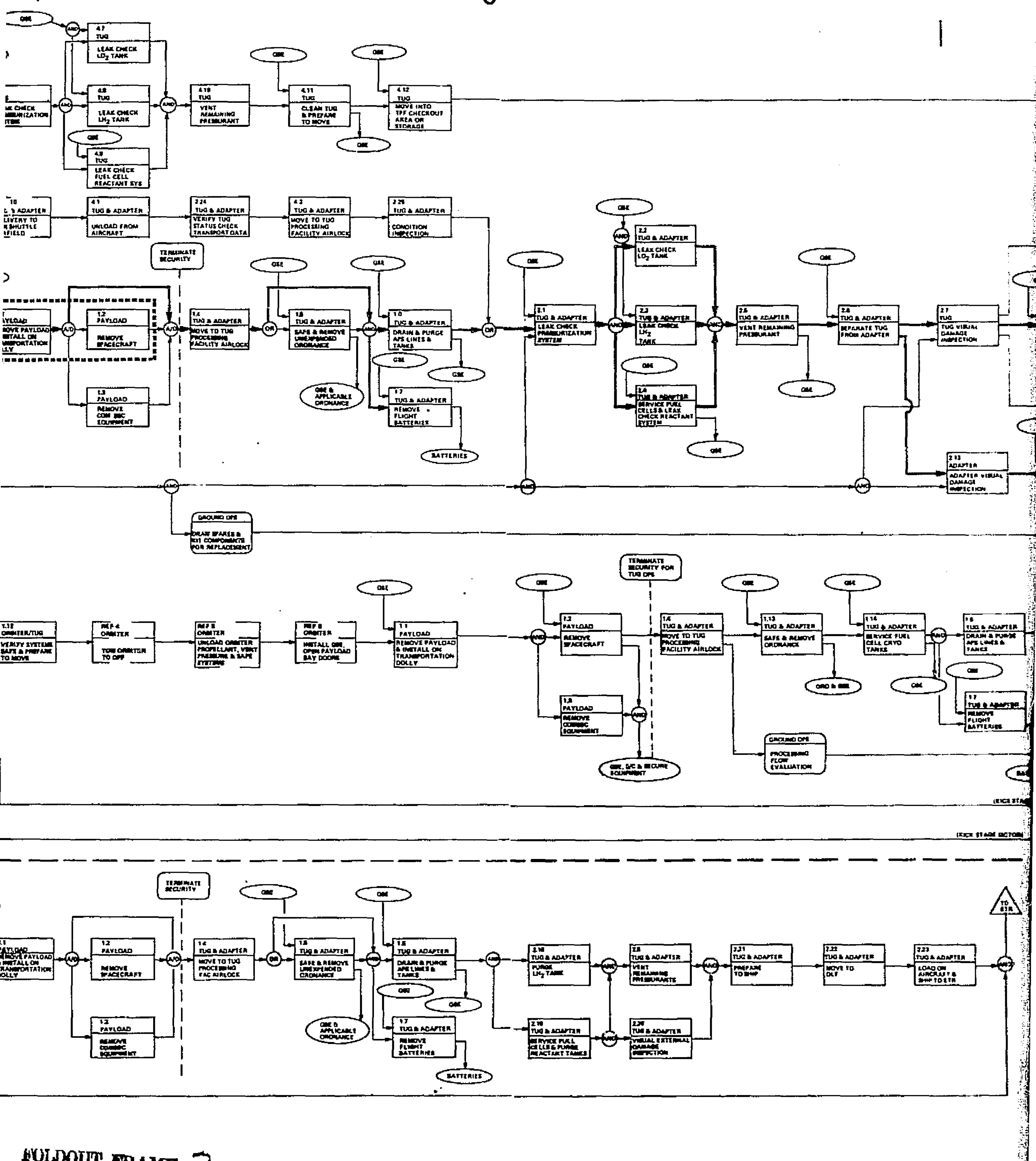

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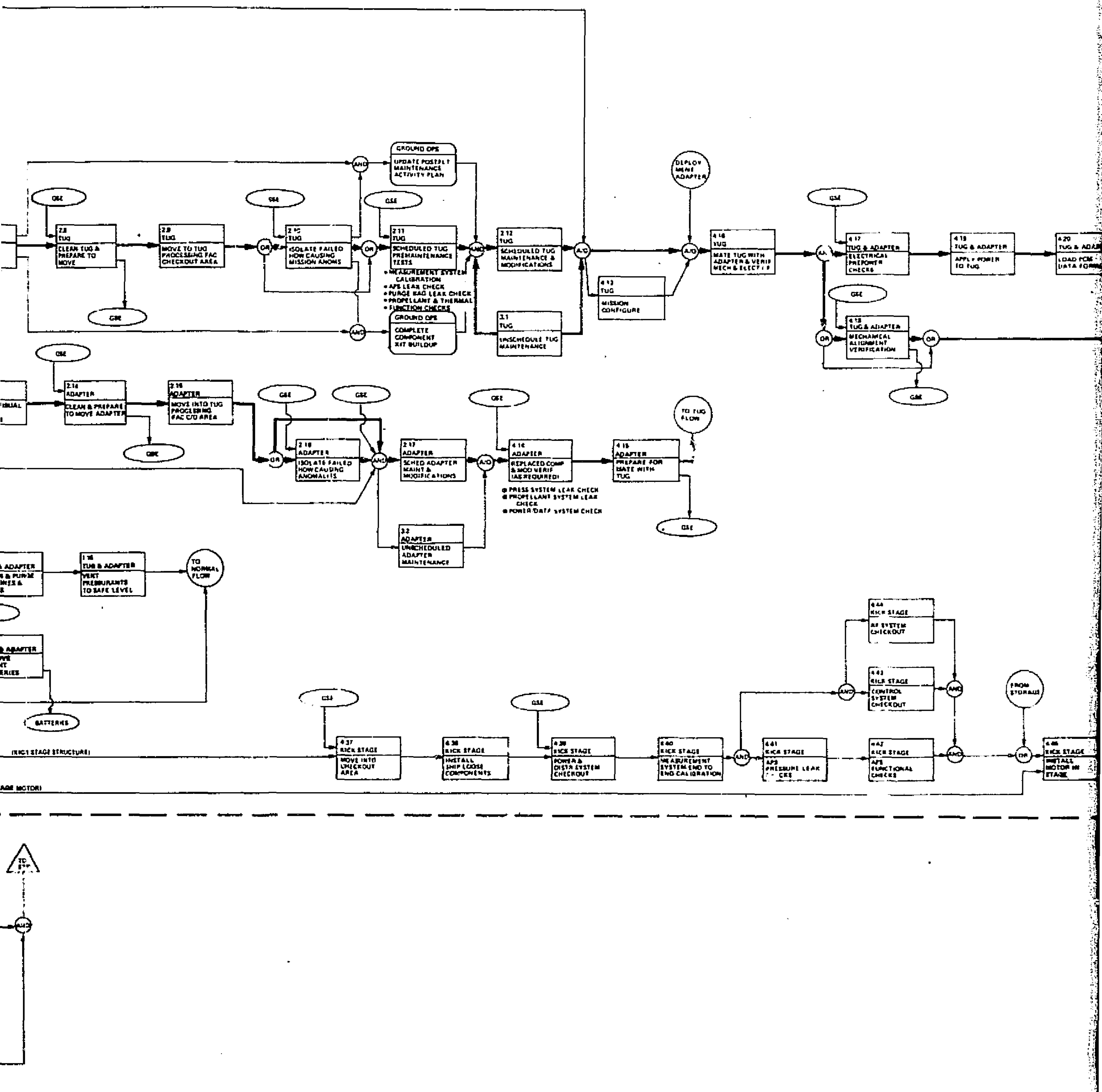
GROUND OPS
UPDATE POSTFLT MAINTENANCE ACTIVITY PLAN
TUG
CLEAN TUG & PREPARE TO MOVE
TUG
MOVE TO TUG PROCESSING FAC CHECKOUT AREA
TUG
ISOLATE FAILED HDW CAUSING MISSION ANOMS
TUG
SCHEDULED TUG PREMAINTENANCE TESTS
TUG
SCHEDULED TUG MAINTENANCE & MODIFICATIONS
MEASUREMENT SYSTEM CALIBRATION
APS LEAK CHECK
PURGE BAG LEAK CHECK
PROPELLANT & THERMAL
FUNCTION CHECKS
GROUND OPS
COMPLETE COMPONENT KIT BUILDUP
TUG
UNSCHEDULED TUG MAINTENANCE
TUG
MISSION CONFIGURE
DEPLOY MENT ADAPTER
TUG
MATE TUG WITH ADAPTER & VERIF MECH & ELECT I/F
TUG & ADAPTER
ELECTRICAL PREPOWER CHECKS
TUG & ADAPTER
APPLY POWER TO TUG
TUG & ADAPTER
LOAD FOR DATA FORM
TUG & ADAPTER
MECHANICAL ALIGNMENT VERIFICATION
ADAPTER
CLEAN & PREPARE TO MOVE ADAPTER
ADAPTER
MOVE INTO TUG PROCESSING FAC C/O AREA
ADAPTER
ISOLATE FAILED HDW CAUSING ANOMALIES
ADAPTER
SCHED ADAPTER MAINT & MODIFICATIONS
ADAPTER
REPLACED COMP & MOD VERIF (AS REQUIRED)
PRESS SYSTEM LEAK CHECK
PROPELLANT SYSTEM LEAK CHECK
POWER/DATA SYSTEM CHECK
ADAPTER
PREPARE FOR MATE WITH TUG
TO TUG FLOW
ADAPTER
UNSCHEDULED ADAPTER MAINTENANCE
TUG & ADAPTER
VENT PRESSURANTS TO SAFE LEVEL
TO NORMAL FLOW
BATTERIES
KICK STAGE
RF SYSTEM CHECKOUT
KICK STAGE
CONTROL SYSTEM CHECKOUT
FROM STORAGE
(KICK STAGE STRUCTURE)
KICK STAGE
MOVE INTO CHECKOUT AREA
KICK STAGE
INSTALL SHIP LOOSE COMPONENTS
KICK STAGE
POWER & DISTR SYSTEM CHECKOUT
KICK STAGE
MEASUREMENT SYSTEM END TO END CALIBRATION
KICK STAGE
APS PRESSURE LEAK CHECKS
KICK STAGE
APS FUNCTIONAL CHECKS
KICK STAGE
INSTALL MOTOR IN STAGE
STAGE MOTOR)
GSE
AND
OR
A/O

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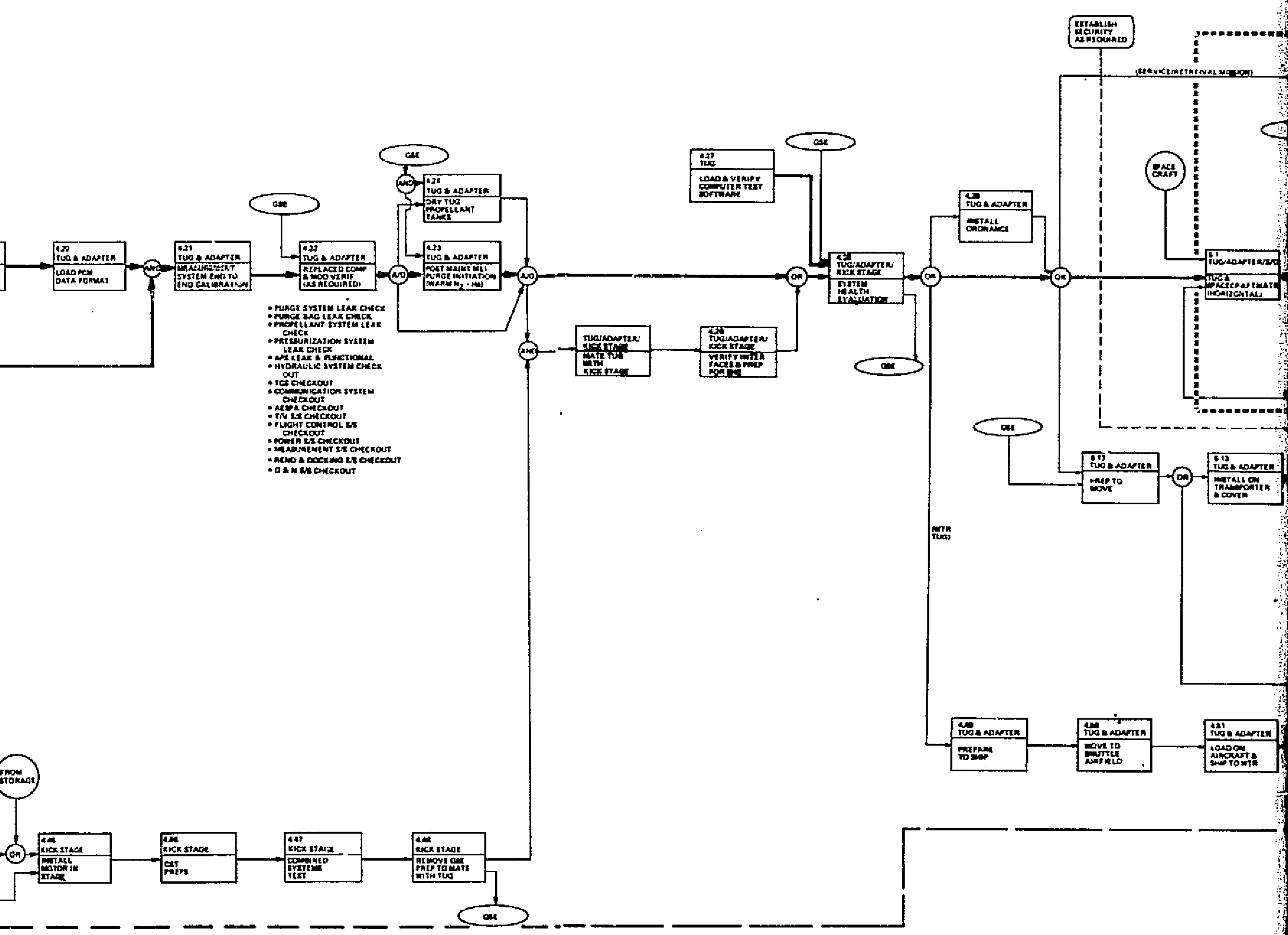

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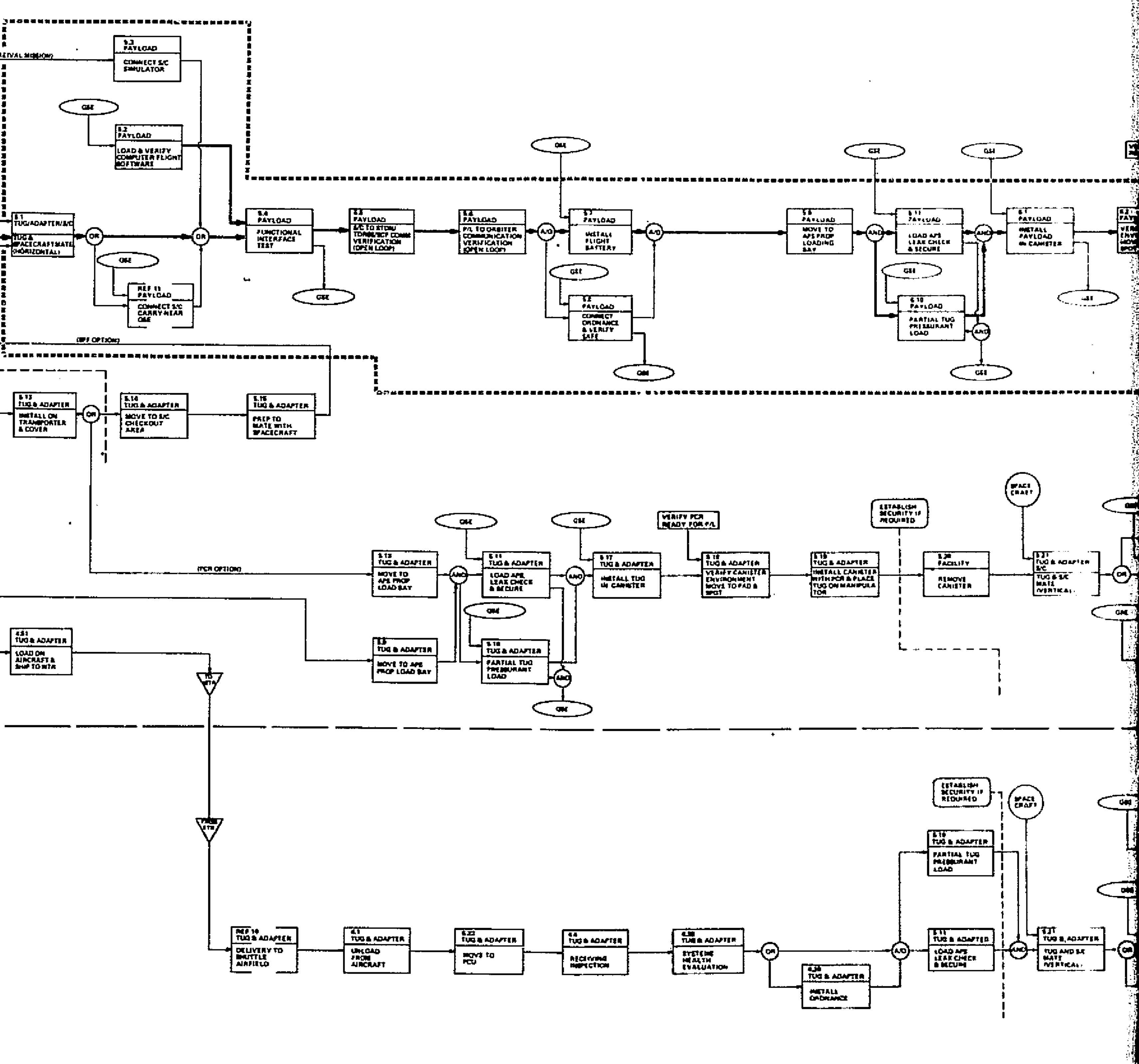

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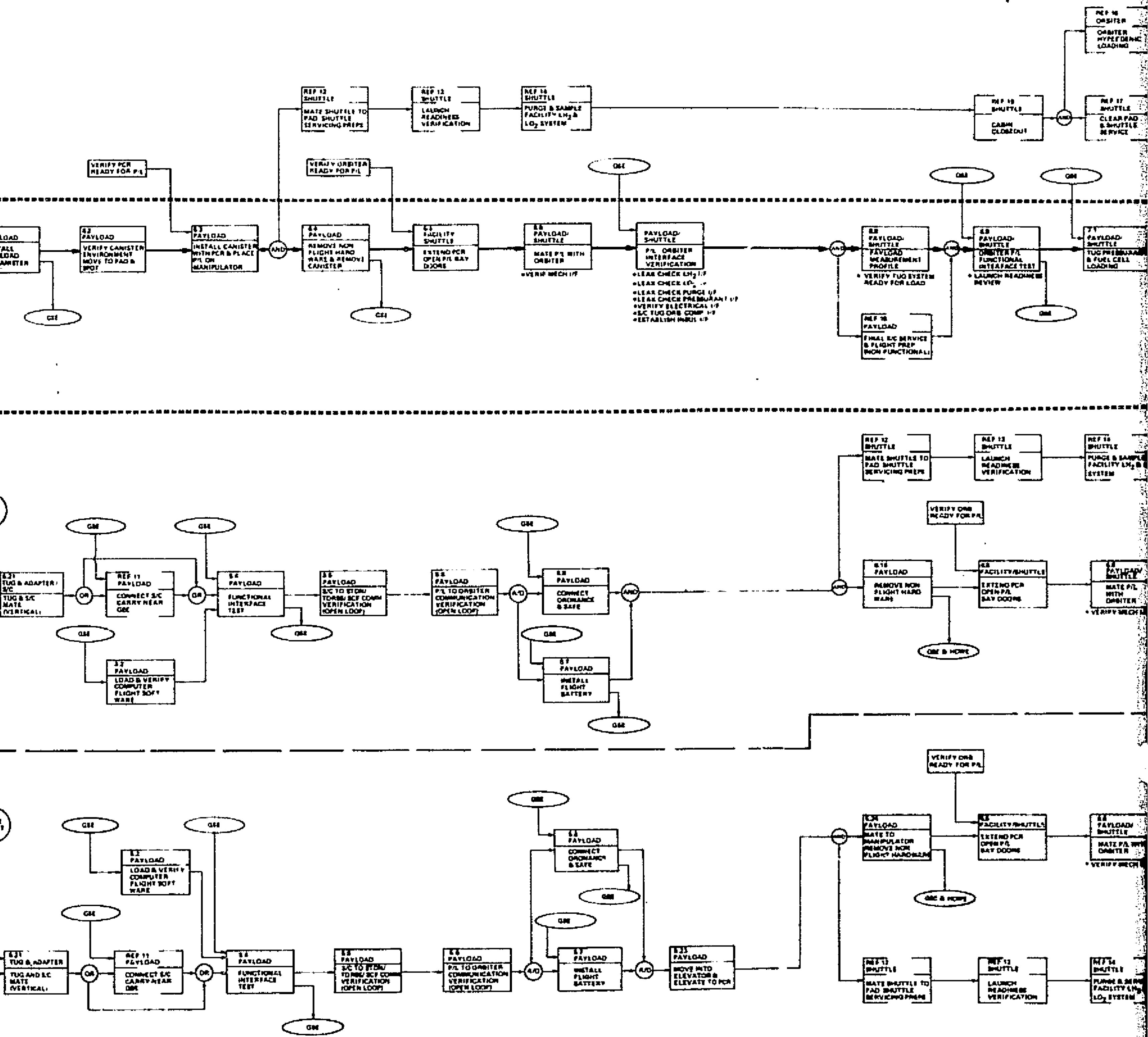

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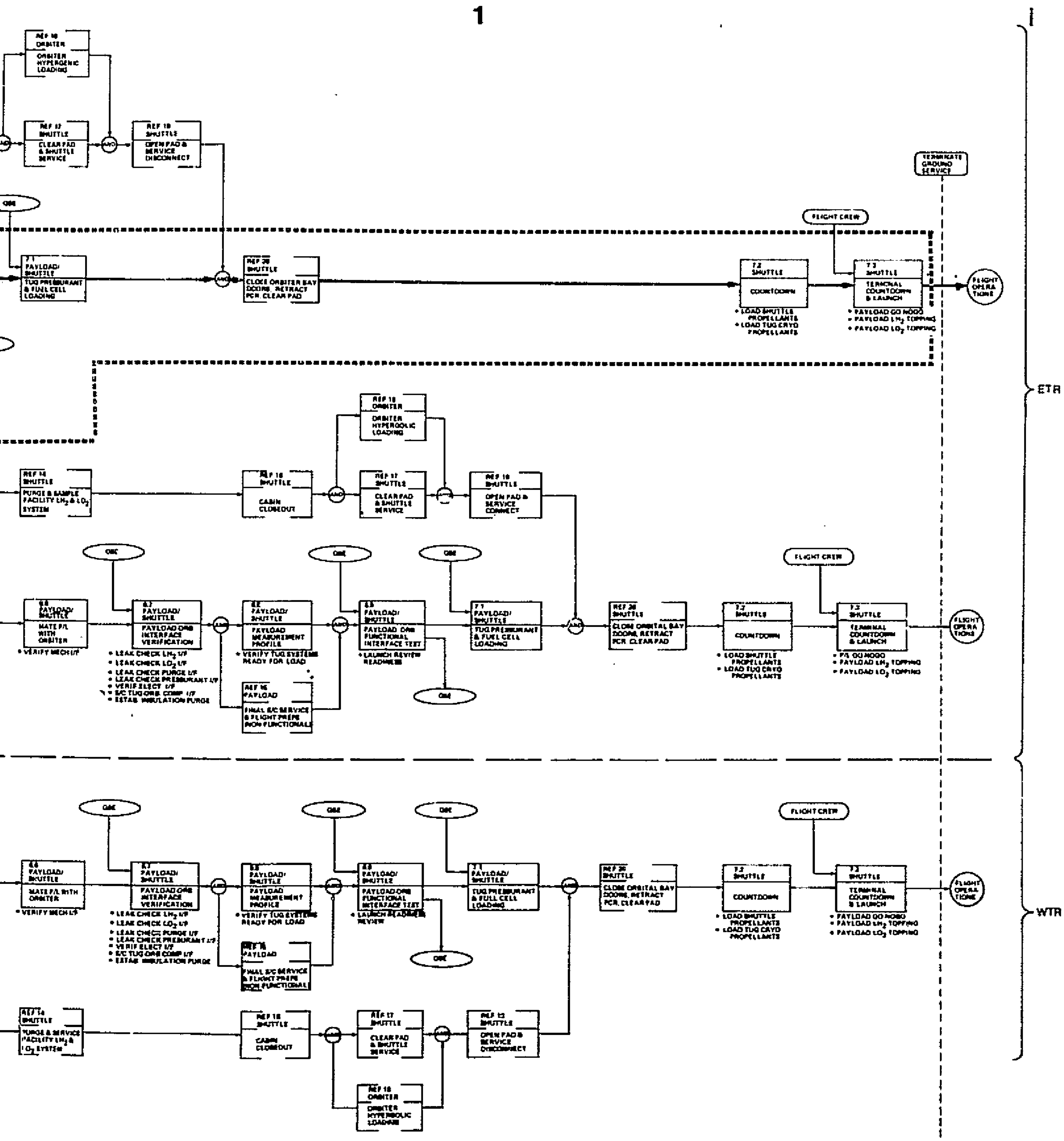


Figure III-C-2 Tug Ground Operations Functional Flow Diagram, Payload Integration Functions

payload processing and recommendations for on-site versus off-site integration for each multiple payload category requires tradeoff analyses. In order to establish the preferred mode for processing multiple payloads, detail flows, facility and resource requirements, and contingency modes were assessed to determine launch site impacts. Requirements and procedures for interface verification of multiple payloads will vary significantly according to degree of payload integration at the time of Tug to spacecraft mating. Even for nominal green light processing, analysis has shown that multiple payload integration on Tug may add between 20 and 30 hours of serial processing time to the Tug turnaround cycle. If individual payload elements are first joined during Tug to payload interface verification, the potential for interface compatibility problems is also much higher than if the payload arrives as an integrated entity. It is recommended that multiple payload integration be performed off-line before interface verification with the Tug. Multiple payload integration before Tug mating does not necessarily mean integration at the launch site. An assessment should be made of on-site versus off-site multiple payload integration by defining the cost sensitivity of each alternative approach and its influence on payload operations at the launch site.

As depicted in Figure III-C-3, the proposed green light processing is with spacecraft checkout off-line to the Tug. The Tug is mated with the spacecraft in the vertical position at the TPF. After mating, the Tug/spacecraft interfaces are verified and the payload prepared for the functional interface test. This test is a compressed time simulated mission sequence to verify total payload functional and operational compatibility. The launch processing system (LPS) will be used for functional simulation, data monitoring, and recording.

Upon completion of the functional interface test, an open loop communication test between the payload to ground station and payload to Orbiter will be conducted. At this time, ordnance will be installed as required. The payload will be loaded into the canister, moved to the pad, and installed in the payload changeout room (PCR). When the Orbiter is ready for payload mate, the PCR is mated to the Orbiter, the PCR and Orbiter doors opened, and the payload installed in and mated to the Orbiter. Interface tests are then performed before final spacecraft servicing. At this time, the spacecraft is ready for launch.

Upon mission completion, the Orbiter is moved to the OPF, the bay is verified safe, the bay doors opened, and the payload removed. The payload is placed on a demate fixture and the spacecraft removed from the Tug before the Tug is returned to its checkout area.

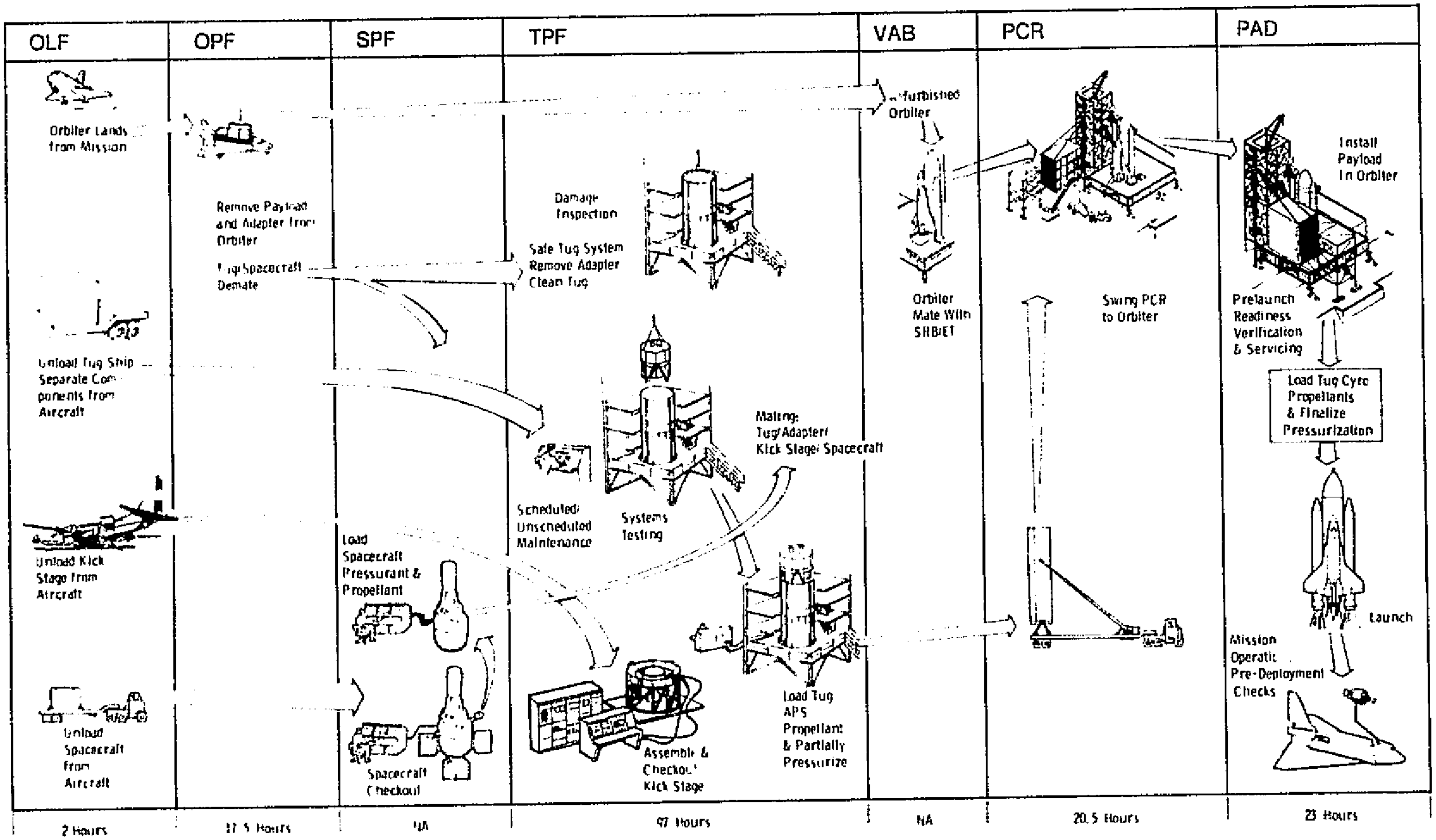


Figure III-C-3 Tug Ground Operations Flow

There is some concern about available space in the OPF to perform the separation of spacecraft from Tug. Another option would be to move the entire payload to the TPF and separate the Tug from spacecraft at that facility. This requires one additional move for every spacecraft retrieved and is not the preferred approach.

3.1.2 Stick and Ball Chart - The complete chart is provided in subplan A. For clarity, the segment affection the payload is included in Figure III-C-4. It shows that the spacecraft will be mated with the Tug at the TPF, and there will be 63 hours before launch to accomplish the operations described in the preceding paragraph. The spacecraft is involved in mating and integrated checkout with the Tug at the TPF for 14 hours, and is installed in the Orbiter bay 23 hours before launch, followed by 6.5 hours of prelaunch checkout. The payload is functionally ready for launch at T-12 hours. Only final servicing remains. The stick and ball chart also shows that the spacecraft demate from the Tug will occur approximately 20 hours after landing.

3.2 Facility and GSE Requirements

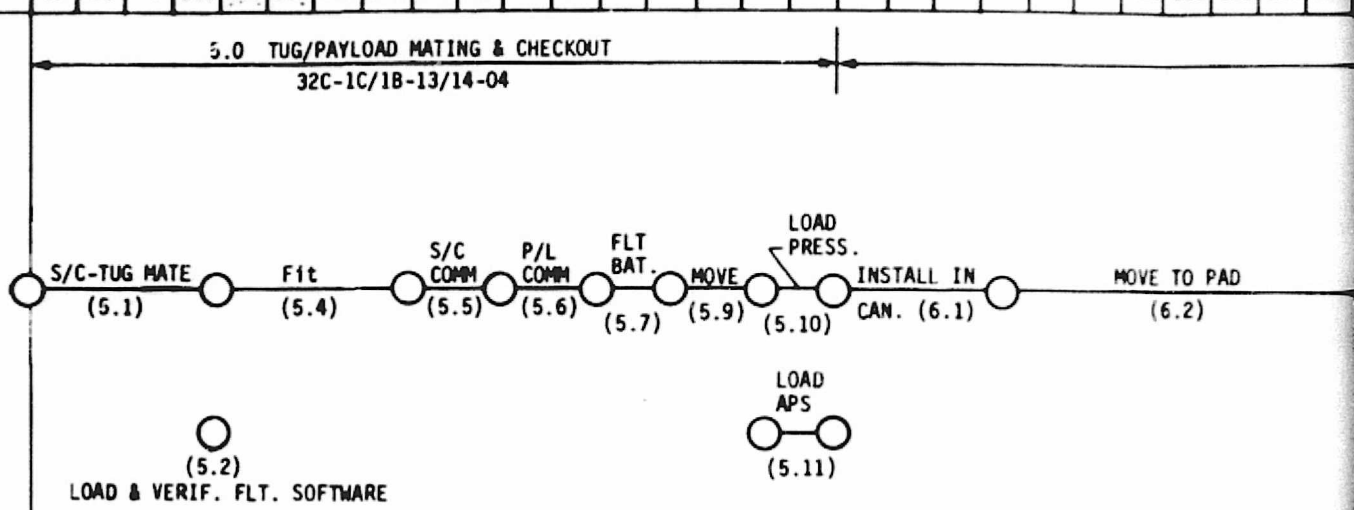
3.2.1 Facilities - The spacecraft will be mated with the Tug and the payload checked out in a 100K clean area of the TPF. If the SAEF-1 is selected for TPF, the entire processing area is a 100K clean facility. If the VAB is selected, only the area immediately surrounding the spacecraft will be 100K clean. On completion of payload interface verification between the Tug and the spacecraft interface, verification between the payload and Orbiter will be performed in the TPF test cells to accomplish Level I integration objectives. Several previous studies have identified the requirements for the Off-Orbiter Interface Verification. These requirements are based on the premise that launch schedule confidence can be improved by payload-Orbiter compatibility demonstration before installation in the cargo bay. Level I integration has been defined as follows:

1) Verify interfacing hardware developed by different agencies;

2) Integrate ground and flight crews;

3) Provide the disclosure point for system, design, schedule, and logistic errors.

SHIFTS	13								14								15								16			
HOURS	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124



*INCLUDES FACILITY SUPPORT MANPOWER

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TOTAL MANPOWER *	32	32	32	34	36	36	36	36	18	18	18	18	17	17	14	21	33	33	3	33	33	26	26	26	14	14	14	14
TEST CONDUCTOR					1	1	1	1	1	1	1	1				1	1											
TEST ENGINEER	1	1	1	2	2	2	2	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PROPULSION TECHNICIAN	1	1	1	1	1	1	1	1								4	4	2	2	2	2							
MECH/STRUCT/THERM TECH.	3	3	3	3	1	1	1	1					1	1				3	3	3	3							
AVIONICS TECHNICIAN	1	1	1	2	4	4	4	4	2	2	2	2	1	1		1	1	1	1	1	1							
SAFETY ENGINEER	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
QUALITY CONTROL TECH.	1	1	1	1	2	2	2	2	1	1	1	1	1	1		1	1	1	1	1	1							
TECHNICAL SUPPORT	8	8	8	8	8	8	8	8	3	3	3	3	3	3	3	3	8	8	8	8	8	8	8	8	3	3	3	3
MANAGEMENT SUPPORT	8	8	8	8	8	8	8	8	1	1	1	1	1	1	1	1	8	8	8	8	8	8	8	8	1	1	1	1

FACILITIES
FACILITY SUPPORT MANPOWER
1ST SHIFT 8 MEN
2ND SHIFT 8 MEN

PROP LOAD AREA

PAYLOAD

GSE

A-001, A-017
P-008

A-001, A-008
A-009, A-011
A-012

A-001
A-006

A-001
A-006

A-001
A-005
H-021

H-018
H-024
H-025

A-005
P-011
P-016

A-005, H-018

A-001
A-008
A-009

P-011
P-012
P-017
P-018

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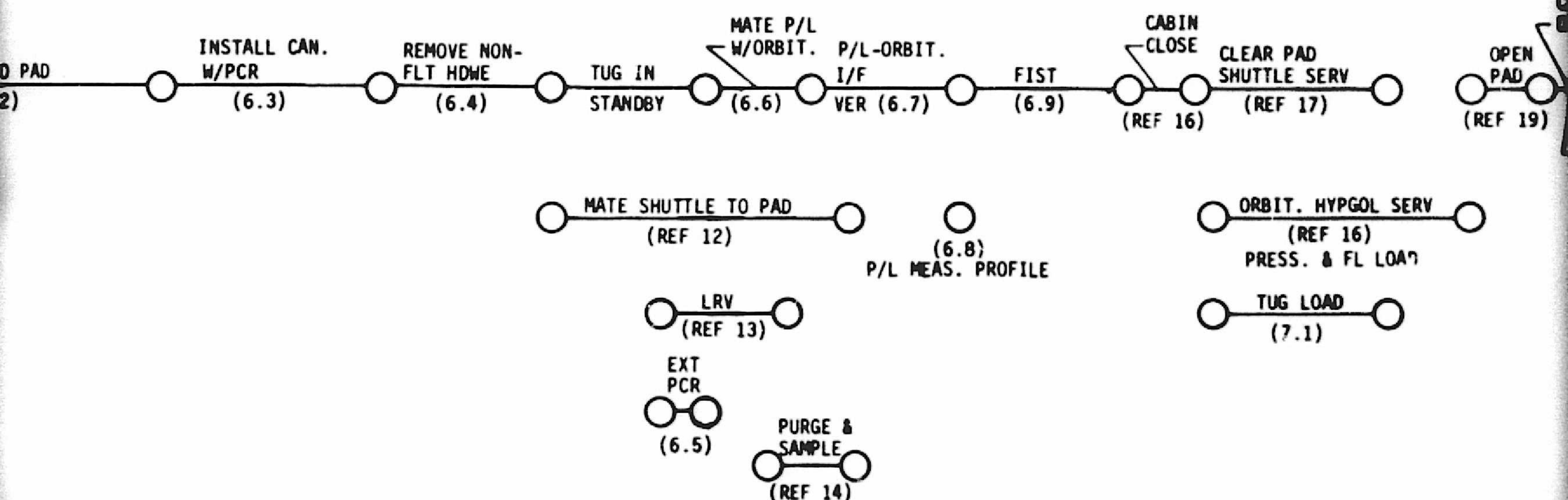
							19								20				

6.0 TUG/SHUTTLE MATING & CHECKOUT
32C-1C/1B-09/10-02

7.0 PRELAUNCH CHECKOUT & COUNTDOWN
32C-1C/1B-09/10-03



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1	1	1	1	1	1	1	1	1	1	1	1	1	1			1
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1	1	1	1	1	1	1	1	6	8	8	8	8	8	8	8	1

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1	1	1	1	1	1	1	1	1	1			1	1	1	1				
2	2	2	2	2	3	2	2	2	2			1	1	1	1				
3	3	3	3	3	3	3	8	8	8	8	8	8	8	8	3	3	3	3	3
1	1	1	1	1	1	1	8	8	8	8	8	8	8	8	1	1	1	1	1

LAUNCH PAD

PAYLOAD CHECKOUT ROOM (PCR)

IN ORBITER

GFE ONLY REQUIRED TO SUPPORT TUG

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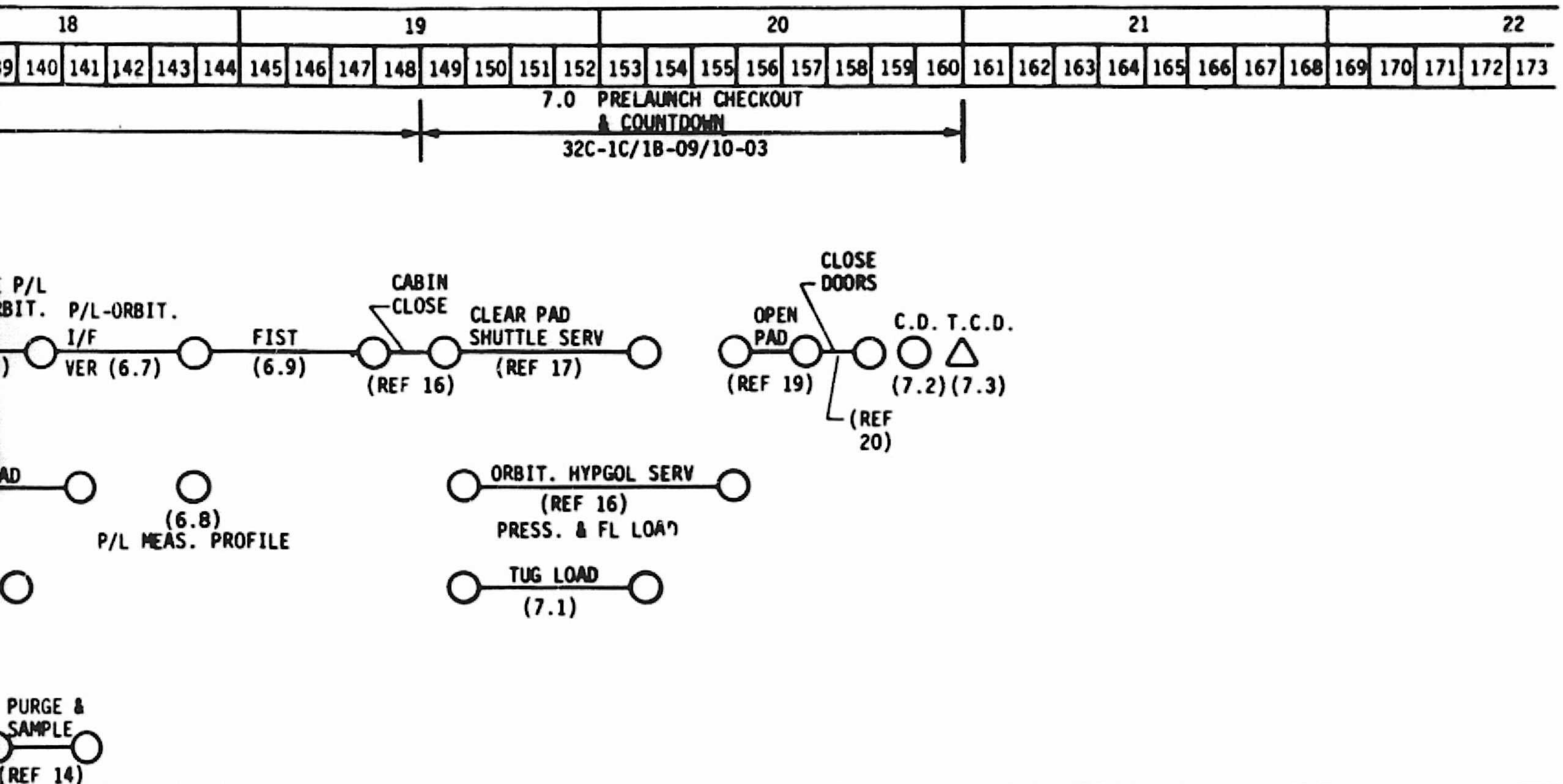

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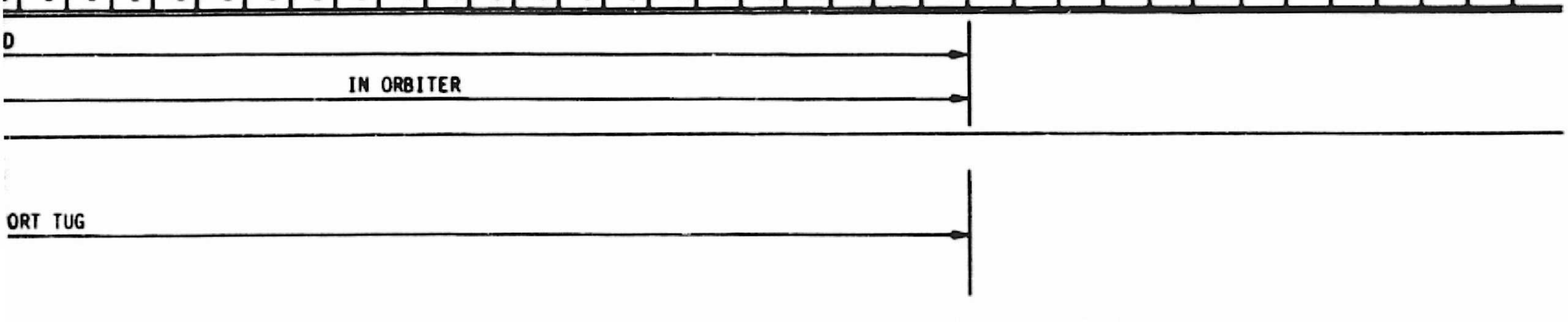

Figure III-C-4 Tug/Spacecraft Stick and Ball Chart

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Although the Level I off-line integration concept has been widely accepted, within the definition numerous alternatives are available for implementation. Because many of the Tug interfaces become standard, the interface verification device for the Tug and its payload need not be as sophisticated as the Level I integration device of other Orbiter payloads. Our recommended approach, shown on Figure III-C-5 is referred to as the TPF Orbiter simulator. This concept provides the capability to verify all payload/Orbiter interfaces during the normal payload ground operations process. The approach uses the Tug/spacecraft integrated test cell as the final interface verification point before payload transfer to the pad. One advantage is the minimum equipment required to implement the objectives. The baseline processing flow generated during Task 1.0 derived the requirements to provide Orbiter cabling, payload unique equipment of the MSS/PSS, and RF open loop testing with the controlling ground station. The Orbiter MSS/PSS equipment and Orbiter payload support equipment are the only additional equipment required for Level I integration.

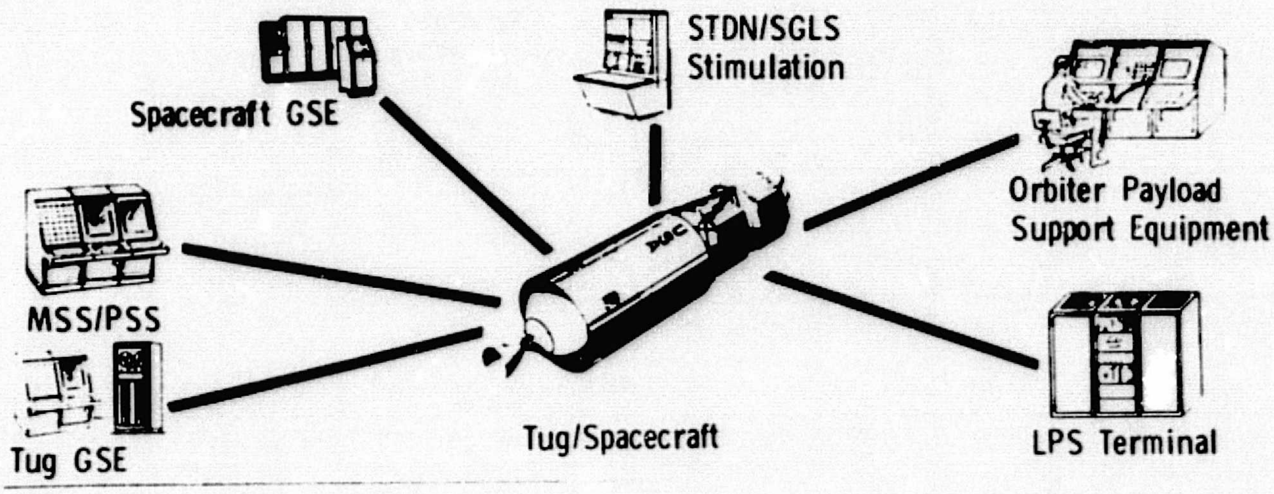


Figure III-C-5 TPF Orbiter Simulator

On completion of the TPF activities, the payload will be moved to the launch pad and installed in the PCR. The green light flow does not identify any specific checkout operations while in the PCR. All nonflight items will be removed from the payload at this time. The PCR will be maintained 100K clean to support these activities. The payload will interface with the PCR from the bottom or side to accommodate vertical payload installation. The PCR manipulator will extract the payload from the canister, position it in the PCR, and insert it in the Orbiter payload bay after the PCR has been mated to the orbiter.

A requirement for payload changeout at the pad could occur because of either failures/contingencies or priority payload considerations. One of the Special Emphasis Assessments evaluated payload changeout, considering three alternative approaches. The complete assessment is documented in addendum 4 to this report. These include spacecraft changeout only, Tug changeout only, or total payload changeout. Spacecraft changeout only involves two options: (1) remove Tug to PCR or (2) leave Tug in Orbiter. Payload changeout has major impacts depending on the time of occurrence. Spacecraft changeout has been considered under three separate conditions: (1) before loading fuel cell reactants (T-10 hr); (2) before loading cryogenic propellants and flight pressures (T-2 hr); and (3) after cryogenic propellant loading (T-1 hr). Refer to Figure III-C-6 for payload changeout function flow at the pad. To accomplish spacecraft changeout, the first step would be to install the new spacecraft in the PCR while the PCR is still retracted. The PCR would then be extended to the Orbiter, the Orbiter bay doors opened, the payload manipulator extended into the Orbiter bay and attached to the payload.

The payload would be extracted from the Orbiter bay into the PCR (or the spacecraft extracted leaving the Tug in the Orbiter bay as an option). The spacecraft would be separated from the Tug and stowed in the PCR. The new spacecraft is mated to the Tug and functional interfaces are verified. The new payload would then be extended into the Orbiter bay and installed.

For those spacecraft to be flown out of WTR, there are delta requirements. Figure III-C-7 provides a simple overview of the WTR facilities. The Tug is flown to WTR from the TPF at ETR and transported from the landing strip to the payload preparation room (PPR) airlock by prime mover. The prime mover is removed and the Tug is cleaned and moved into the PPR. The spacecraft is mated to the Tug at the PPR and the total payload lifted in to the payload changeout room (PCR). The PCR is translated to the launch pad where the payload is installed in the Orbiter cargo bay. Propellants and pressurants are loaded for the final countdown.

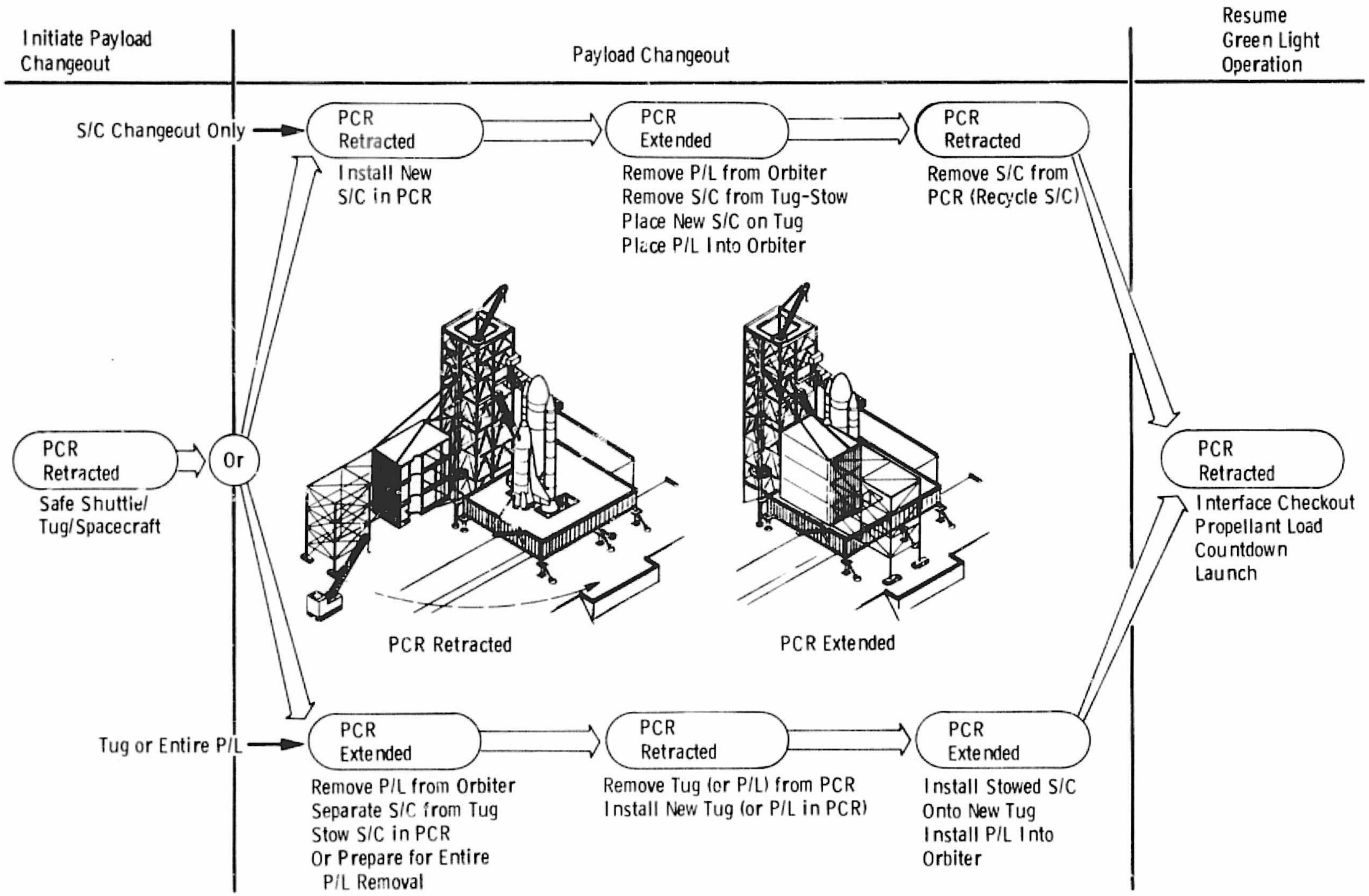


Figure III-C-6 Payload Changeout Functional Flow

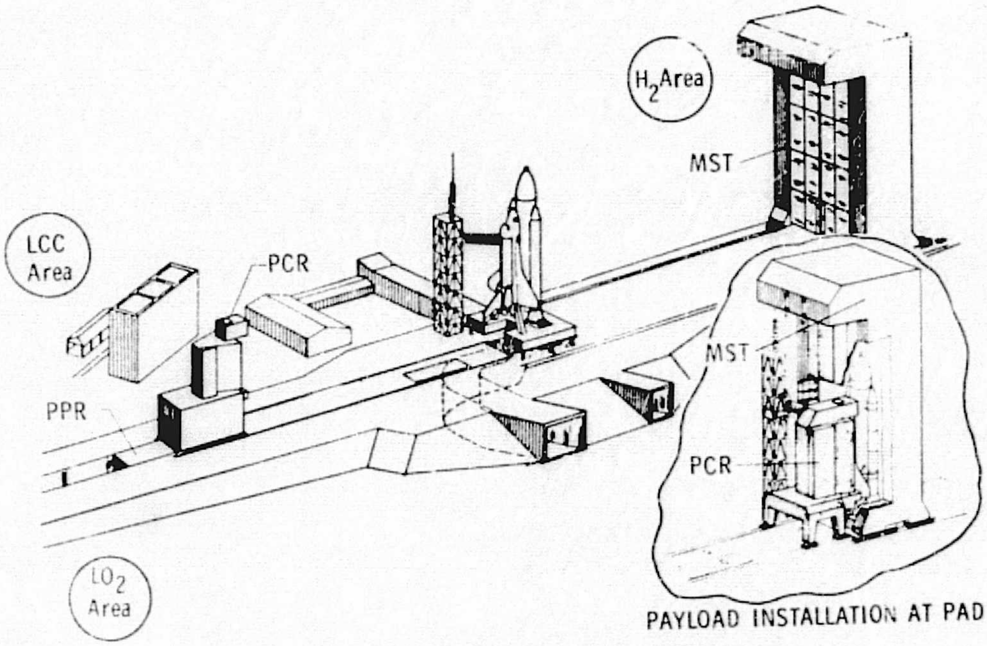


Figure III-C-7 WTR Processing Facilities

3.2.2 Ground Support Equipment (GSE) - All GSE required for spacecraft processing and handling before Tug mate will be the responsibility of the spacecraft owner. The Tug integration agency will supply the required alignment tools and/or fixtures after Tug mate. The primary checkout mode of the payload (Tug/spacecraft) will use the existing launch processing system (LPS). Any spacecraft-unique GSE required for integrated checkout will be spacecraft provided. Any spacecraft requiring better than 100K cleanliness must supply additional equipment such as protective covering, to meet the requirement. It should be noted that, since WTR is designed as an alternative landing site for ETR launches, GSE for recovery, safing, and handling of the Tug and its payload at WTR must be available even if launch capability is not provided at WTR.

The LPS is a concept to perform automatic data processing of launch site operations for the Space Transportation System. These operations include functions such as monitor and control of vehicle and ground support equipment during prelaunch, landing, and turnaround maintenance; flight and ground test data analysis, unit level bench maintenance; and a management information capability. The system uses a distributed processing scheme where console computers are performing in parallel within assigned scope. Each console is supported by a common, large scale processing capability and control data subsystem. Each console computer supports a console group that

will command and monitor functions in its assigned discipline. The system is designed to provide real-time control, data analyses and information display for the checkout servicing, launch, landing, and refurbishment of vehicles, payloads, and GSE.

[illegible] Transportation Requirements and Support

Spacecraft transportation and ground handling before mating will be the responsibility of the spacecraft agency. After physical mating at the TPF, the primary responsibility will belong to the IUS/Tug processing agency. It will revert back to the spacecraft agency at physical separation of the spacecraft from the IUS/Tug after mission return. In the case of alternative or contingency site landing, responsibility will again revert to the spacecraft agency when physical demate occurs.

Normal ground movement of the spacecraft begins with delivery from the spacecraft processing facility to the TPF. The processed spacecraft is transported to the airlock area, transferred by a payload manipulator to the checkout area cell, and installed by crane on the Tug or kick stage. After mating and functional interface tests, the integrated payload is moved by the manipulator from the checkout cell to the airlock. Tug ADS loading and partial pressurant loading occurs in the airlock. After loading, the payload is placed in the vertical cargo canister, transported to the pad and installed in the PCR and then transferred to the Orbiter cargo bay.

Pre-mate spacecraft transportation and handling requirements will be the responsibility of the spacecraft agency and must be developed with sufficient lead time to be integrated into the KSC payload ground operations process flow. Spacecraft developed requirements will define the spacecraft equipment that must be monitored or operated by IUS/Tug personnel. Contingency or emergency procedures for the post-mate processing flow must be highlighted in the requirements data. Unique requirements imposed by the spacecraft on the handling of the integrated payloads must be specified in spacecraft requirements data for integration into KSC transportation and movement plans/procedures. These requirements could include such things as constraints on handling loads, shock or vibrations or special concerns for any environmental conditions during transportation.

Spacecraft changeout by removal of the entire payload from the Orbiter payload bay should not have major design impact on the spacecraft. The spacecraft agency should provide a forward lifting adapter for PCR crane attachment; however, this is probably required for normal spacecraft handling. The PCR crane will remove the spacecraft from the Tug while the Tug is supported by the manipulator, place the spacecraft in temporary storage in the PCR, and reposition a second spacecraft for Tug attachment. If the spacecraft-only is removed from the payload bay by the manipulator, manipulator load/attach points on the spacecraft would be required.

3.4 *Operational Data Requirements*

Not applicable to this subplan.

3.5 *Manpower Staffing*

After the Tug and spacecraft are physically mated, the Tug project is responsible for integrated checkout and processing, and will supply the manpower to accomplish this task as identified by the stick and ball chart.

Spacecraft-supplied manpower will include technical representatives who are responsible for spacecraft status/test evaluation, at all times, and will report this status to the Tug test conductor. Also required will be spacecraft personnel to handle the spacecraft before mate, and to connect and operate spacecraft-peculiar GSE during integrated checkout. Spacecraft-supplied personnel will be required to support a 2-shift per day, 5-day per week operation.

3.6 *Safety Requirements and Support*

Consideration of safety requirements for integration of payloads with the IUS/Tug during ground operations must begin during spacecraft design. For this study, it is assumed that spacecraft will be designed to comply with the safety requirements contained in paragraph 3.2.6.2, Spacecraft Safety, of the Baseline Space Tug Requirements and Guidelines, MSFC 68M00029-1. These requirements include pertinent items such as fail safe interface connections and verification of those connections.

During ground operations, the control authority over a spacecraft will transfer to the IUS/Tug processing agency at physical mating. This transfer of control imposes special safety requirements on the spacecraft agency to ensure safe processing of the mated Tug/spacecraft.

The first requirement is to identify for the IUS/Tug processing agency all residual hazards associated with the spacecraft. The residual hazards identification must include all conditions that could affect the safety of the IUS/Tug, the operating crew, and the environment. Typical concerns include high and low temperatures, pressurized systems, hazardous materials, ionizing radiation, and pathogenic experiments or specimens. The residual hazard identification must also define the hazard control requirements and the potential effects of an undesired event.

Post-mating spacecraft-unique handling and checkout requirements are the responsibility of the spacecraft agency. Normal operating procedures will include appropriate precautionary (Warning or Caution) notes preceding any step in which a malfunction or error could result in personnel injury or equipment damage. Emergency procedures will also be developed to provide for safe backout, or limit the extent of effects of hazardous conditions.

The spacecraft agency will also be responsible for providing portable hazard monitoring equipment that may be required. Spacecraft containing elements that generate hazardous conditions, such as pressures or temperatures, must be monitored and controlled. Portable hazard monitoring equipment will provide these functions during mated transportation and handling activities.

3.7 Fleet Utilization and IUS/Tug-to-Spacecraft Integration Requirements

The subplan has defined the affect of payload operations on launch site requirements. This section will define those considerations unique to the planning era of Tug/spacecraft integration. These data are provided to assist the payload integration agency in defining concepts that consider all aspects of payload processing and integration, and will not be limited to activities involving physical integration at the launch site.

One of our previous studies evaluated the candidates for payload integration. The results were reassessed to determine the applicability to the IUS/Tug. In general, the criteria for evaluation and the results are appropriate. These criteria are shown on Figure III-C-8.

That study concluded that either an independent integrator or the carrier--in this case, the IUS/Tug--best satisfied the criteria. Since the present interface concept is moving toward most interfaces between the spacecraft and Orbiter being routed through the IUS/Tug, the IUS/Tug project is the most logical choice for payload integration, single or multiple spacecraft.

3.7.1 <u>Analytical Integration</u> - Many Tug missions involve multiple spacecraft (40%). Multiple payload missions require management and analytical integration as well as coordination during launch site processing. It is necessary to establish that all elements (Tug/spacecraft or Tug/multiple spacecraft) that make up the total payload are compatible with each other. This involves the decision to verify compatibility by analysis or by test to establish that they have no functional, thermal, electronic, or mechanical interferences. This analytical integration would be started by the payload integrator during the planning phase of the mission and continued throughout the program. Based on results of a spacecraft questionnaire, the following analysis may be required to be

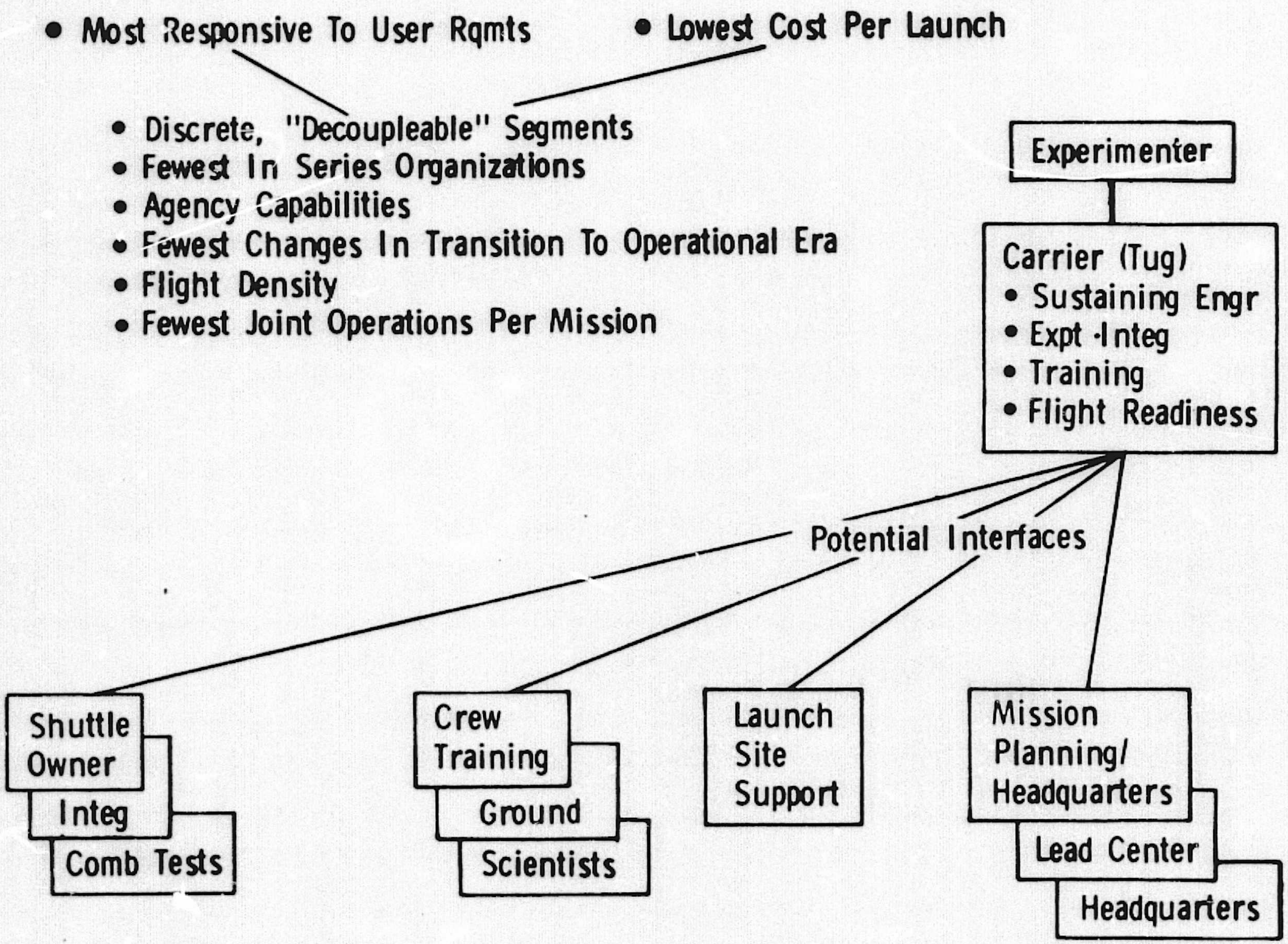


Figure III-C-8 Criteria for Selection

performed by the payload integrator. Not all would be performed for each mission, only those where spacecraft requirements were marginal or exceeded Tug capabilities.

3.7.1.1 *Design Loads* - Required preliminary design loads analysis should be started as soon as possible, preferably when a spacecraft is first under consideration for a Tug payload.

3.7.1.2 *Thermal Analysis* - Depending on program schedules and the amount of spacecraft design support required, preliminary thermal analysis may be performed during the design development phase. The integration agency should perform the required prelaunch and inflight analysis during the initial phases of Tug/spacecraft integration.

3.7.1.3 *Trajectory Analysis* - A planning trajectory analysis is normally performed 18 to 30 months before launch, and its complexity varies with the spacecraft dependence on Tug avionics interface (guidance and control). The trajectory analysis is an open-loop guidance and control system, three-degree-of-freedom, point-mass analysis that is based on preliminary spacecraft mission requirements and nominal Tug performance characteristics.

3.7.1.4 *Mass Property Management* - This task includes the development of the mathematical model to evaluate mass properties of the integrated payload and their effects on performance parameters when required.

3.7.1.5 *Contamination Analysis and Control* - This task is required to establish that the gaseous and particulate environment of the integrated payloads is compatible with the STS requirements as well as assurance that self-induced effluents and operations do not jeopardize the performance of the payload.

3.7.1.6 *Special Studies* - This task should identify, as early as possible, special problem areas to be assessed and the recommended alternative solutions, as required. These data would be oriented toward evaluating the total payload operations and integration activities to eliminate or reduce launch site activities.

3.7.2 Interface Verification - Based on analytical integration decisions, the payload integrator would then be responsible for determining test requirements for those interfaces to be verified by test. These test requirements would involve spacecraft to spacecraft interfaces as well as spacecraft to Tug interfaces. In addition to the test requirements, a plan must be developed to assure accomplishment of the required tests and analysis to verify compatibility. This task would define the integration activities requiring simulators, fit-check devices, software required, and other integration equipment (including flight hardware) required for each interface verification concept. This

task should define the participation of each piece of hardware to accomplish the actual data verification crossing each interface.

3.7.3 Tug User's Guide - Handbooks and/or user's guides are most applicable to operational elements where the change rates are low and the systems are well defined. The handbook must guide the users through the various phases of the program from payload and experiment conception and development through the integration cycle to launch site processing, and launch and recovery operations. Standard interfaces must be defined for the user. Mandatory and no-risk criteria must be established. Capabilities in terms of support provided for the users must be defined, operating procedures established, and the documentation system defined. Safety and integration requirements must be defined. The user's guide must inform the user how and with whom the user's equipment interfaces.

The Tug user's guide would require both the Shuttle user's guide and the appropriate handbooks as source data and should include specific criteria that apply to the experiment/spacecraft. The Tug user's guide content should contain those elements necessary for the payload integration agency to perform its task as the single point contact for the areas of safety, facility management, technical support, administrative functions, and verification of interfaces. Primary emphasis should be placed on standardizing interfaces and reducing the required documentation at the launch site. A recommended outline for development of a Tug user's guide is provided in section 5.0 of this subplan.

3.7.4 Software Requirements - The magnitude of software verification is also a variable involved in upstream payload integration activities. Special studies may be required, because of relative costs, required integration equipment, operational alternatives, and applicability to payload categories, to determine if a reduction of software verification can be made when similar payloads are involved. This task would define the guidelines to analyze the software and operational and interface problems before and during program development with the goal of cost reductions.

3.7.4.1 Software Integration - Although the required software integration activities may be reduced it is doubtful that all interface verification requirements will be eliminated. This function should define the required integration tasks for verifying LPS and Tug/spacecraft compatibility. This data should include functions such as monitor and control of the payload and ground support equipment during prelaunch, landing and turnaround maintenance; flight and ground test data analysis; unit level replacement; and management information.

Data should present the representative hardware, breadboards, and simulators required for total software integration before launch site usage.

3.7.5 Mission Operations - Although mission operations *per se* are not a concern of the ground processing flow, those elements of rendezvous, stationkeeping, servicing, and ground station interfacing that require prelaunch checkout are a concern. Data presented here must be in unison with the on-going mission simulation approach. This task should indicate where, how, and when ground test activities should be conducted, and how they should be interrelated to assure timely integration with existing or planned STS simulation facilities.

3.8 Site Activation and Verification

An engineering model will be the first Tug through the launch site facility after the construction phase. This model will be used to verify facility and GSE interfaces in the TPF, PCR/pad, and OPF. It will be used to verify LRU removal/replacement techniques and handling. Spacecraft and kick stage simulators will be used to verify mating, payload handling, and systems level verification. The first flight article flow through the processing sequence is identical to the flow for all flight articles. Eleven months would be required for site activation and on-pad checkout, providing an actual flight spacecraft is used to support site activation.

3.9 Ground Software Development

IUS/Tug software for payload integration requires that the spacecraft needs be identified. The spacecraft contractor may request from the IUS/Tug some initiating functions and health status of the lower elements as inputs. Possible spacecraft operational outputs that require IUS/Tug software for processing are spacecraft health monitors and feedthrough spacecraft status, C&W, and self-check information. The spacecraft may levy software requirements on the IUS/Tug in the form of orbital functions, such as attitude, velocities, spin, separation restrictions, deployment sequence, final check, etc. The information exchange is a two-way operation. The IUS/Tug should prepare a list of functions it could perform for the spacecraft.

The situation of a new payload arriving and entering the ground processing sequence every few days makes efficient integration mandatory. Standardization of services and software will help. The IUS/Tug contractor or a payload integrator will control the ground software development process and input software requirements to the software contractor. Experience with spacecraft and experiments has shown that software requests will not be orderly,

the reaction time requirements will be shorter, the requests will be more nonstandard, and changes will be more frequent. The bulk of the nonrecurring software preparation during the operational phase is expected to be centered around spacecraft integration.

Eventually, there will have been enough spacecraft processed that software development will be the modification of existing routines. The software contractor will maintain a file of software modules available for fast, quick changes that will aid the spacecraft integration process. New sensors, new spacecraft, and new operations will require more software work for spacecraft than for the Orbiter.

Software developed for classified operations would be requested in the same manner, through classified documentation, and would be made secure. Testing, debug, and use would be performed on a different machine than unclassified operations. There are hardware and software cost advantages to using dedicated software and hardware for security. The obvious preparation, handling, and operations restrictions are not unworkable.

2.10 Logistics/Maintenance

Consideration of interface logistics requirements must be accomplished early during both spacecraft and IUS/Tug support requirements analysis. Coordination will be required between the spacecraft and IUS/Tug logistic agencies so that necessary design tradeoff and procedural planning can be accomplished. Considerations of standard connector mate/demate, maintenance access, and general implementation of the LRU concept should be reflected in spacecraft design. Component items that could fail during post-mate processing must be replaceable/repairable within the timeline constraints. Standardization of servicing points and support equipment that can facilitate IUS/Tug agency operations and reduce support time and cost should be implemented.

Maintenance and repair on the spacecraft is assumed to be minimal after mate and only of a contingency nature or based on failure indicated by integrated test. The spacecraft supervisory representative to the IUS/Tug processing team would make the determination for an unscheduled replacement and a spacecraft technician would physically accomplish the replacement with support from the IUS/Tug personnel as required.

Spacecraft spares would normally be drawn from the spacecraft processing facility for LRU replacements at the TPF or PCR. Replacements would normally be accomplished at the TPF. Unique requirements for the handling, storage, or processing of spares not under the control of the spacecraft agency must be procedurally documented or handled by special consideration decal or attachment to the spares.

No requirement for training of IUS/Tug agency personnel by the spacecraft agency is predicted unless the spacecraft presents a potentially hazardous condition during the post-mate flow. If checkout or servicing operations by IUS/Tug personnel involves unique connector mate/demate or other functions not performed by spacecraft personnel, training by the spacecraft agency may be appropriate. Conversely, spacecraft agency personnel who operate in support of the IUS/Tug personnel will require training/certification in the safety and facility interface areas so they can function in the KSC environment. Specific training will be required in clean area procedures to be followed at the TPF and PCR.

3.11 Payload Configuration Management

Not applicable to this subplan.

3.12 Timeline Funding

Not applicable to this subplan.

4.0 Tug Approach to Level I Integration Requirements

4.1 Introduction

The Orbiter to Payload (Tug/spacecraft) interfaces can be numerous and complex. Interface verification techniques must provide the capability to establish flight readiness of all payload to Orbiter interfaces. The ground operations process flow must accomplish the verification without impact on the Orbiter schedule while assuring the Tug/Payload a high confidence of accomplishing its mission objectives. The interfaces requiring verification may belong to many different organizations and consist of different levels of state-of-the-art equipment.

4.2 Scope

The scope of this assessment was to define the recommended approach to accomplish Level I integration objectives from a payload integrator's point of view. This task will define interface verification objectives, establish what equipment is required for accomplishment, and assess various concepts for satisfying these objectives.

4.3 Typical Payload Interfaces

The major interfaces concerning the payload integrator can be grouped by subsystems such as structures, mechanisms, fluids and avionics as shown in Figure III-C-9. Interfaces can be further segregated into test and checkout, safety and safing, environmental and cleanliness, and DOD peculiar requirements. This special emphasis study is limited to those test and checkout interfaces that can be verified before launch pad mate with the Orbiter. "Prior to launch pad mate" does not necessarily limit interface verification to the launch site.

4.4 Hardware Interfaces

Detailed payload to Orbiter interfaces are being developed by parallel studies performed during the course of this study, based on the characteristics of the Tug, kick stage, and spacecraft. All defined interfaces were assessed. The avionics interface, defined by General Dynamics Corporation in the first data exchange meeting and illustrated in Figure III-C-10, is the more complex.

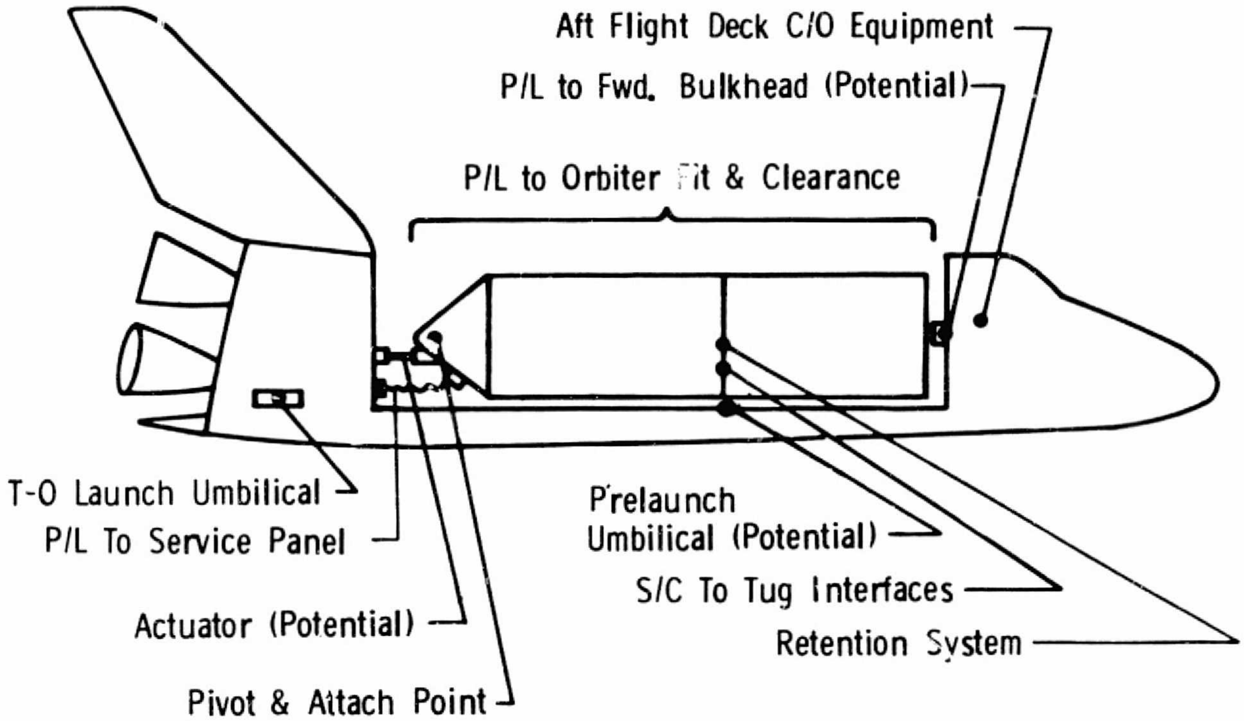


Figure III-C-9 Payload Interfaces

Software interfaces have not been defined. However, it can be implied from Figure III-C-10 that software will have a major impact on the ground operations processing flow. The situation of a new payload arriving and entering the ground process to meet traffic requirements makes efficient integration mandatory. Standardization of services and software will enhance the integration of software. Past experience with spacecraft and experiments has shown that software requests will not be orderly, the reaction time requirements will be shorter, the requests will be more nonstandard, and changes will be more frequent. The bulk of the nonrecurring software preparation during the operational phase is expected to be centered around payload integration with the Orbiter and the LPS.

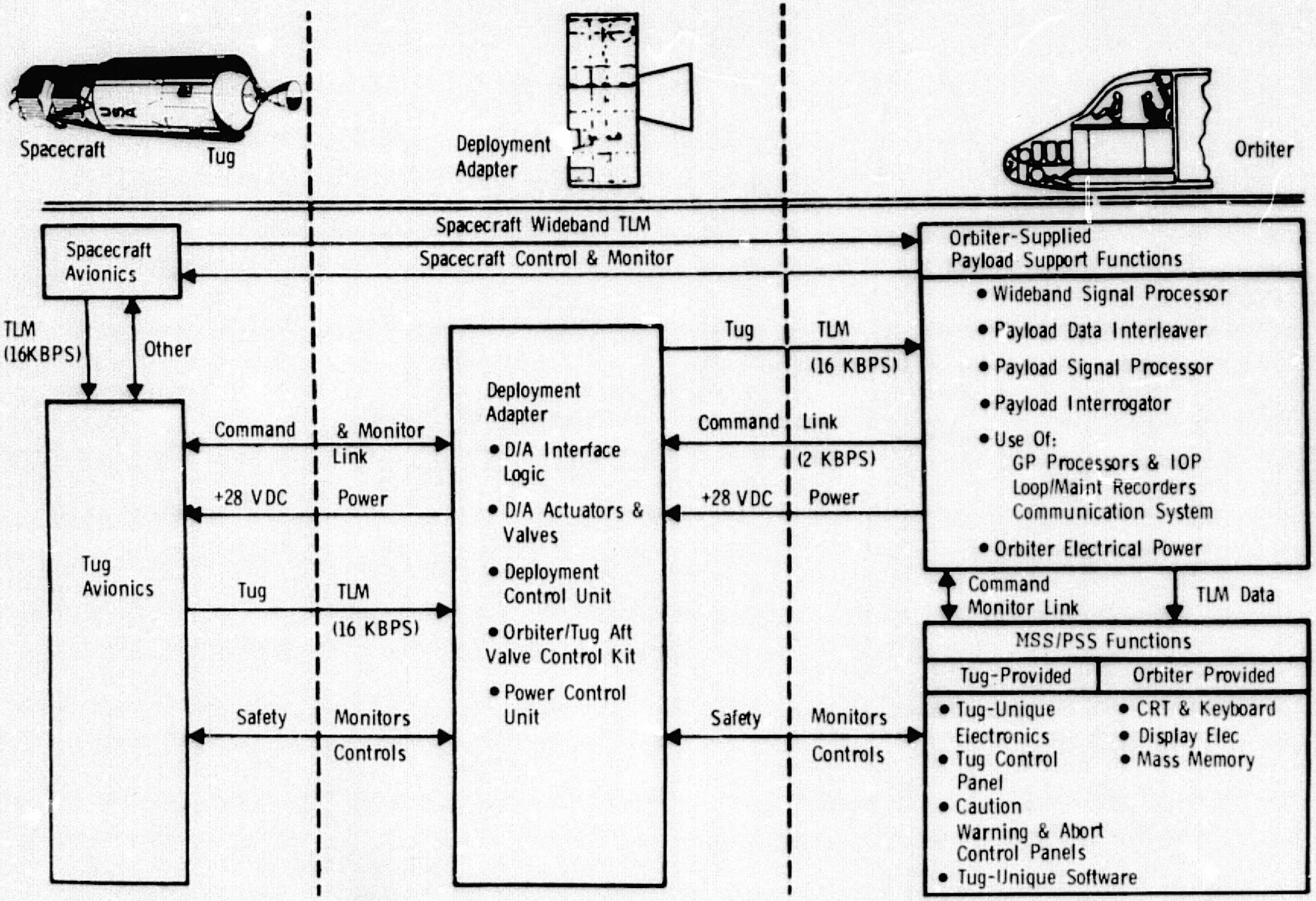


Figure III-C-10 Avionics Interface

4.6 Interface Verification

The payload to Orbiter interfaces can be complex on multiple payload missions, especially in the avionics system and associated software. Previous studies indicate that 40% of Tug payloads are multiple candidates combining two or more spacecraft with the Tug (in some missions a kick stage) into a single mission. Such multiple payload missions require management, analysis, and interface verification during launch site processing.

4.6.1 Interface Verification Objectives

A comparison of interface verification objectives developed by NASA-KSC with resources required for accomplishment is shown on Figure III-C-11. It reveals that most applicable objectives can be accomplished when the first few Tugs are processed, with or without a spacecraft. The primary reason is that all payload to Orbiter interfaces are through the Tug. The Tug to Orbiter interfaces become standard when operational. Some spacecraft, of course, require direct interface with the Orbiter (gases and fluid only) that would be provided by kits and would be verified on each mission.

	Resources													
Objective	Retention System	Orbiter Umbilical	Orbiter Wiring	MSS/PSS Orbiter	MSS/PSS Payload	Crew	Ground Station	LPS	Tug	Spacecraft	GSE	PCR	Canister	Orbiter Payload Supplied
Verify payload and GSE physical fit interface.									x		x	x	x	
Assess post-landing payload anomaly.								x	x	x	x			
Verify payload to cargo bay physical fit interface.	x	x			x				x					
Payload system fault isolation.			x	x	x			x	x	x	x			
Verification payload element to element fit and functional interfaces.		x	x	x	x	x	x	x	x	x	x			x
Verify payload to Orbiter system functional interfaces.			x	x	x	x	x	x	x	x	x			x
Verify payload to launch complex systems.	←							NA						→
Software validation test bed.			x	x	x	x	x	x	x	x	x			x
Develop payload launch procedures and crew relationships.	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Specific mission simulation situation.	←							NA						→
General purpose payload repair station.	←							NA						→
Minimize SID function by treating each objective as far upstream in the payload pipeline as practical.	←							NA						→

Figure III-C-11 Objectives vs Resources

C-4

Two objectives require some type of Level I integration device: (1) verification that all system interfaces between the payload and Orbiter are functional, and (2) software validation between the LPS, Tug computer, spacecraft computer, the controlling ground station, and other software interfaces.

4.6.2 Upstream Responsibility

Although this assessment is launch site oriented, interface verification commences at the developer's facility. The Tug, spacecraft, and experimenter must demonstrate during upstream testing that the vehicles are operational and flightworthy. This study is based on the philosophy that performance verification testing should be conducted remote from the launch site and that only flight readiness and interface verification should be verified at the launch site.

4.7 Recommended Level I Integration Approach

It is the conclusion of this study that the payload to Orbiter interface verification can be performed incrementally using the following steps:

1) Impose the Tug user's guide as a compliance document on all potential users for standardizing interfaces and reducing launch site documentation;

2) Employ a modular simulation approach for design verification type testing of spacecraft during the DDT&E phase.

3) Accomplish all common interface verification objectives between Tug/adapter to Orbiter with the first few Tugs processed;

4) Perform software integration at an off-line simulation laboratory before TPF payload processing;

5) Perform total payload to Orbiter interface verification of TPF vertical test cell with active Orbiter MSS/PSS and payload support equipment.

4.7.1 Tug User's Guide

Section 3.0 established that handbooks and/or user's guides are most applicable to operational elements where the change rates are low and the systems are well defined. The handbook must guide users through the various phases of the program from payload and experiment conception and development through several integration cycles (experiment to carrier, multiple spacecraft, spacecraft to Tug, and total payload to Orbiter), to launch site processing, and launch and recovery operations. Interfaces must be defined

for each user and any mandatory and no-risk criteria must be established. Capabilities in terms of support provided for the users must be defined, operating procedures established, the documentation system and safety and integration requirements defined. The user's guide must define in detail what is expected of the user and how and with whom the user's equipment interfaces. Section 5.0 of this subplan provides a recommended Tug user is guide outline.

4.7.2 Modular Simulation

A major factor in reducing the extent of launch site interface verification is to raise the level of testing. This philosophy emphasizes that performance verification testing should be conducted remote from the launch site, and interface verification, including flight readiness, should be verified at the launch site. Modular simulation is a cost effective and versatile method for accomplishing performance verification off-site. Individual interface simulators, physical fit simulators, master gauges, and tools could be used for most spacecraft performance verification. These tools and simulators could have mobility, as required, to accommodate the spacecraft developer at his facility. Although no single modular simulator would provide total simulation (including software), it would reduce the number of unexpected events and the test and integration time at the launch site.

4.7.3 Tug Engineering Model

Assessment of the interface requirement indicates that most interfaces to the Orbiter are via the Tug and/or its adapter. Spacecraft to Orbiter interfaces are limited and would be provided by a kit. These interfaces are fluid and gases only, and could be verified during initial installation of the kits. As indicated, with the exception of the avionics interfaces and associated software, the payload to Orbiter interfaces can be verified during the first Tug mate with or without a spacecraft. These interfaces tend to become standard as the Tug becomes operational.

In subplan D the requirement for a Tug engineering model (pathfinder) was established to facilitate site activation. This vehicle will accomplish most interface verification objectives associated with standard Tug to Orbiter interfaces.

4.7.4 Software Integration

Recurring software integration is of prime concern to the payload integration agency. The recurring software application programs and some support programs result from changing components, systems, methods, payloads, and requirements. It has been estimated that one-third of the required software functions will require contingency software attention. The orderly expansion and modification of software at each test sequence is achieved by proper care in sizing and using standard data base modification methods.

Although it is surmised that the Tug software will be routine as the Tug becomes operational, it is subject to change because of the Tug being the link between the spacecraft and Orbiter. Refer to Figure III-C-12 for typical payload-Tug-Orbiter-ground station,

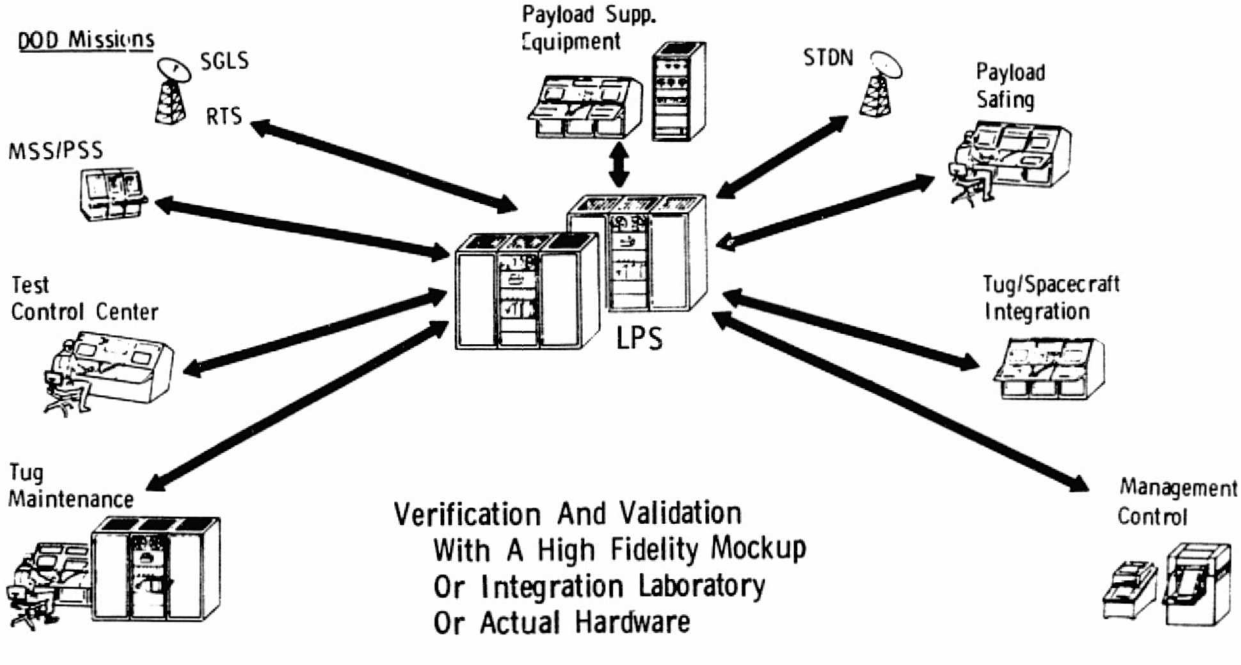


Figure III-C-12 Typical Software Interfaces

It is recommended that software integration be performed off-line to payload processing in two phases. Software integration begins during the programming production phase (Phase I). This checkout and debugging process is accomplished with the LPS computer playing into standard simulation routines. These simulation routines simulate interfaces and monitor inputs and outputs for desired processing.

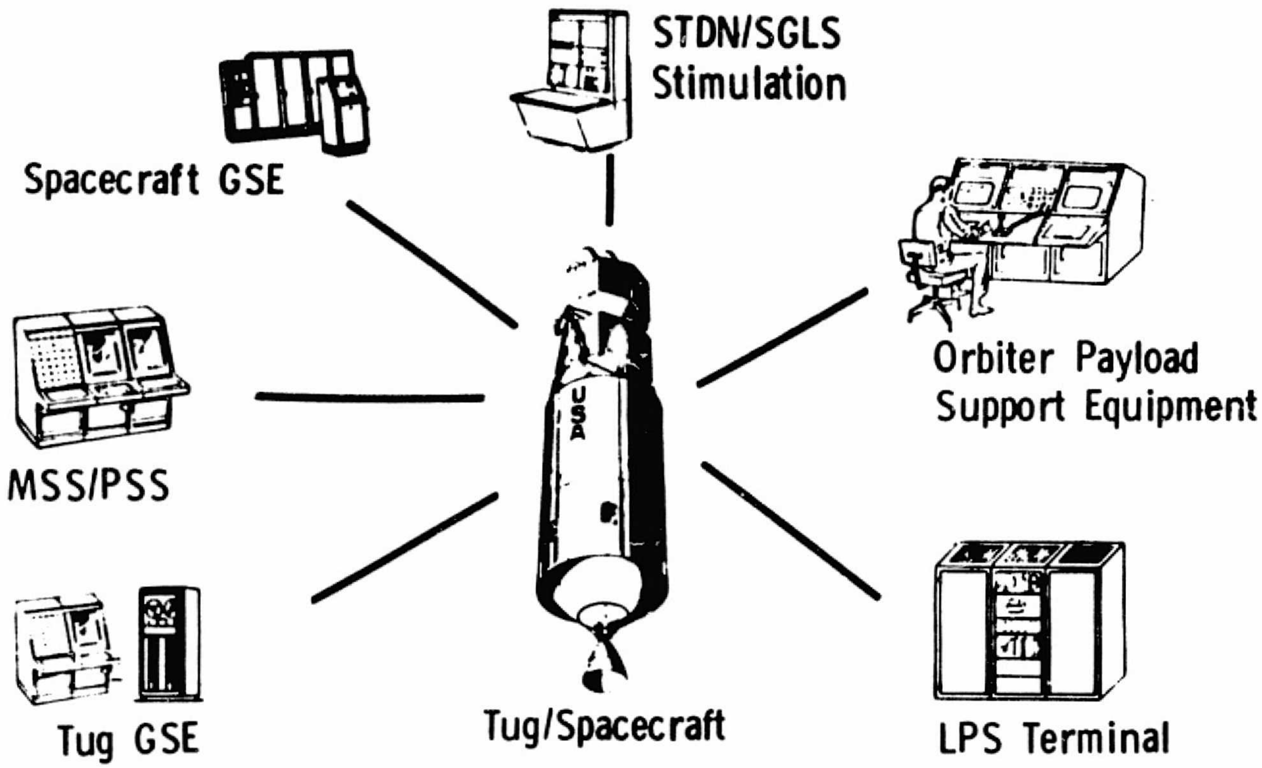
The simulation routines verify that no undesired reactions take place on the remainder of the interface. The checkout and debugging process is accomplished at the software contractor's facility on his LPS hardware with his software and simulation routines. It would be desirable that the element contractor monitor the software checkout and debug to minimize cost because of downstream changes. Since the simulations are with standard software routines, the simulation may be deficient in nonlinear reactions and certain interactions that will be present later during the validation process. This simulator will be limited in checking contingencies and interactions.

Software integration is completed at the end of the verification and validation phase (Phase 2). During this phase, the LPS functions with the developed hardware(or hardware simulators). The hardware can be high fidelity mockup, an integration laboratory with both flight equipment and simulators, or the actual hardware. This validation would probably be performed at a NASA facility because of the amount of hardware required. It could be at an element contractor providing that integration involves a small piece of the STS. The verification and validation is performed with actual interfaces. Very few software simulations should be permitted to increase the quality of the verification. Dynamics and interactions would need to be tested with actual hardware interfaces. The criteria for success would be twofold: (1) outputs would be tested against the first integration (checkout and debug) with one-for-one correspondence present, (2) dynamics of the equipment would be tested against the assigned criteria (or the original job to be accomplished).

4.7.5 TPF Orbiter Simulator

Based on the premise that the first processed Tugs will verify all interfaces except the avionics and associated software and software integration will be accomplished off-line to payload processing, the only remaining objective is to verify payload to Orbiter system functional interfaces. During this study and previous studies, we have assessed various methods and the systems required to accomplish interface verification objectives. These methods included modular simulation, concept verification test (CVT), full scale SIL, and an in-line Level I integration device (TPF Orbiter simulator).

The TPF Orbiter simulator (Fig. III-C-13) provides the capability to verify all payload to Orbiter interfaces during the normal in-line payload ground operations process. This approach would use the Tug/spacecraft integrated test cell at the TPF as the final interface verification point before payload transfer to the launch pad. The major advantages of this approach are; the minimum equipment required to accomplish the objectives, avoidance of any schedule conflicts with a joint usage Level I integration device, and interface verification can be accomplished without another move. The baseline flow generated for subplan A derived the requirements to provide the Orbiter cabling, the payload unique equipment of the MSS/PSS, and RF open loop capability with the controlling ground station. The only additional equipment required would be the Orbiter MSS/PSS equipment, Orbiter payload support equipment, and the crew for total crew/hardware interface verification.



(Orbiter Cabling Required)

Advantages

- Payload Accessability for Limited LRU Replacement
- One Set of Equipment Could Service Two Cells
- Configuration Controlled With Orbiter and Payload
- Concept Could Utilize Some Actual Flight Hardware
- Total Crew and Hardware Interface Verification
- Minimal Additional Hardware

Disadvantages

- Fixed Location at KSC (TPF)
- Tug/Spacecraft Unique - No Joint Usage
- Configuration Control of An Additional Simulator

Figure III-C-13 TPF Orbiter Simulator Concept

5.0 Tug User's Guide Outline

The Tug user's guide can be one of the most useful management tools in the payload integration process, providing it becomes a document imposed on all potential users, instead of a handbook containing general policies and ground rules. A directive user's guide would be of significant value to the payload community, as well as the IUS/Tug integration agency. With appropriate controls, it could be effective during the operational phase of one spacecraft while providing the requirements for spacecraft in conceptual phases. To be effective, the user's guide must be cited as the interface authority before spacecraft conceptual phase for new development, to establish detail interface configuration and management roles.

Making the user's guide a directive document will necessitate early definition of a specific system, which must be included in sufficient detail in the spacecraft documentation for design consideration. If the potential IUS/Tug user is not or cannot become compatible with the standard user's guide interface, then the Tug project could assess all ramifications--design impact, operations, support, maintenance, cost, time, mission objectives, etc. With agreement of the potential user, the project would determine what changes are required to the basic document to accommodate a spacecraft. When the decisions have been made, agreement reached, any exceptions to the user's guide would be specified in an addendum unique to that spacecraft. The basic document with the appropriate addendum would become the contractual payload integration agreement between the IUS/Tug agency and its spacecraft for that mission/flight.

In defining the contents of the user's guide it became apparent that the document is not a one-way instrument. The recommended user's guide consists of four basic elements essential to payload integration: (1) it defines compliances imposed by the Tug for standardization of interfaces and requirements; (2) it contains variable accommodations supplied by the Tug that are negotiable; (3) it defines areas that require specific and/or split responsibilities for integration tasks; and (4) it contains agreements between the Tug and its potential spacecraft on tasks and/or requirements that tend to be unique to each flight/mission.

The following shows the minimum recommended user's guide contents.

Each of these elements are further defined in subsequent paragraphs of this subplan.

1.0 Introduction

The introduction should specify in concise terms the overall objectives of the user's guide. It should be written to portray the guide as applying technical and administrative direction and surveillance to, (1) identify and document the functional and physical characteristics of the Tug, (2) control changes to those characteristics, and (3) provide a means for the potential user to implement his mission objectives. The Tug design, performance, and accommodations should be communicated through the user's guide to the user. The introduction should state that deviations from the data presented in the guide are negotiable, but adherence to the objectives to the fullest extent possible is desirable so that interfaces may be standardized to an optimum degree.

1.1 Scope

The scope briefly outlines the extent of the work and agreements necessary to achieve the objectives. Reference should be made to the controlling directive document that cites the guide as the authoritative document to which the payload integrator and user must adhere to accomplish the objectives.

2.0 Tug Essential Data

2.1 Space Transportation System

This section should be limited. In general terms, the capabilities of the Space Shuttle System to accommodate payloads for delivery into Orbit and return to earth should be described. Performance data, subsystems capabilities and interface provisions, environments and support equipment of the Shuttle should be condensed and

limited to relevant material for reader convenience and orientation into the STS world. Reference should be made to appropriate documentation that reflects the baseline Space Shuttle System.

2.2 *Tug System Description*

This section should specify the physical and functional characteristics of the Tug as a payload carrier. It should contain a functional description of the Tug at the system level. It should include, as a minimum, mission capabilities (with a typical mission profile), total payload weight available to the potential user, either directly or by reference.

2.3 *Tug Payload Accommodations and Constraints*

This paragraph should depict each physical and functional interface. Interfaces should be stated in quantitative forms, with tolerances where applicable. Descriptive material should be included to incorporate, either directly or by reference, a control drawing or equivalent representations. The graphic portrayal should be accomplished to the level of detail necessary to illustrate the functional operation of each subsystem, the relationships between these functions, and the relationships between the functions and other identified subsystem/equipment functions. Descriptions for separately identified subsystem functions should be portrayed in subsequent paragraphs as appropriate. The subsequent paragraphs should include, as a minimum, the following data to describe the capabilities of the Tug.

2.3.1 Mission Requirements

2.3.1.1 *Launch Schedule*

2.3.1.2 *Orbit Parameters*

1) Apogee and Limits

2) Perigee and Limits

3) Inclination and Limits

4) Eccentricity and Limits

2.3.1.3 *Launch Window Parameters*

1) Orbit Lifetime

2) Eclipse Time Constraints

3) Orbit Inclination Limits versus Time

2.3.1.4 Spacecraft Separation Parameters

1) Velocity Limits

2) Rate-of-Angular-Change Limits (pitch, yaw, roll)

3) Timing (multiple-release time delays)

4) Latitude and Limits

5) Longitude and Limits

6) Orientation and Limits (pitch, yaw, roll axes)

2.3.1.5 Preseparation Functions

1) Identify Equipment Deployment (e.g., spatial envelope, cg changes)

2) Equipment Deployment Timing (e.g., time before separation, time between events)

3) Acceleration Constraints (pitch, yaw, roll, longitudinal) during and after Deployment

2.3.1.6 Postseparation Tug Capability

1) Operations (e.g., complete shutdown, special orientation)

2) Post-separation Maneuver (e.g., time delays, Separation, Distances before initiation, Orientation, New Orbit Identification, Minimum Velocity Additions)

2.3.1.7 Special Trajectory Capability

1) Thermal Maneuvers

2) Spacecraft Release over Telemetry or Tracking Ground Station

3) Maximum or Minimum Position Drift Rate

4) Telemetry Maneuvers

2.3.2 Spacecraft Characteristics

2.3.2.1 Physical Envelope

1) Shape (e.g., dimensioned assembly drawing)

2) Volume

3) Coordinate System (spacecraft relative to Tug)

2.3.2.2 *Mass Properties*

1) Weight (e.g., total, separable, and retained masses)

2) Center of Gravity (e.g., cg locations about the three reference axes of total, separable, and retained masses)

3) Moment of Inertia (e.g., inertia about the three reference axes of the total, separable, and retained masses)

4) Product of Inertia (e.g., product of inertia with respect to the three-axis cg of the total, separable, and retained masses)

2.3.2.3 *Structural Stiffness*

1) Natural Frequencies below 50 Hz

2) Mode Shapes below 50 Hz

3) Interface Stiffness Matrices

4) Mass Matrices (dynamic model)

2.3.2.4 *Handling Constraints*

1) Ground Transport (e.g., orientation with respect to earth)

2) Handling Limits (e.g., acceleration constraints)

2.3.2.5 *Critical Orientation during Checkout, Prelaunch, In-Orbiter, and On-Orbit*

1) Antennas (e.g., location, direction, beamwidth)

2) Sensors (e.g., location, look angle)

3) Other Critical Elements

2.3.2.6 *Ordnance Items*

1) Identity and Function

2) Installation (i.e., when, where, and by whom supplied, installed, and connected)

3) Shorting Plugs (i.e., when, where, and by whom supplied and installed)

4) Electrical Characteristics (e.g., no-fire current, all-fire current, bridgewire resistance, pin-to-case resistance)

5) RF Susceptibility (i.e., pin-to-case, pin-to-pin, and bridge-wire-to-bridgewire RF susceptibility, and input impedance)

2.3.2.7 *Safety Items*

1) Identify items (e.g., cryogenics, corrosive fluids, high-pressure gases)

2) Item Characteristics (e.g., quantity, pressure, radiation levels)

2.3.2.8 *Thermal Characteristics*

1) Thermal Math Model (i.e., an analytical tool containing the thermal nodes and conductors; the emissivity, absorptivity, conductivity, and resistivity characteristics and the thermal-node view factors of the Tug)

2) Heat Sources (i.e., identity, location, orientation, amount, times, and duration of heat generated)

3) Node Limits (i.e., maximum and minimum allowable temperatures per node)

2.3.2.9 *Contamination Control*

1) Ground Conditions (e.g., constraints before and after Tug/spacecraft integration)

2) Inflight Conditions (e.g., during ascent trajectory before and after orbiter separation)

3) Critical Surfaces (i.e., type, size, location)

4) Surface Sensitivity (e.g., susceptibility to propellants, gases, and exhaust products)

2.3.2.10 *Separation System*

1) Separation Mechanism (e.g., design of fasteners, clamps, springs, lanyards, and loose hardware)

2) Separation Loads (e.g., reactions, shock, spinup torques)

3) Separation Rates (e.g., longitudinal, lateral, and radial)

2.3.2.11 *Grounding Philosophy*

1) Structure (e.g., use of structural grounds, current levels)

2) Electrical Equipment (e.g., grounding technique for black boxes, power supplies)

3) Single-Point Ground (e.g., location, related equipment)

2.3.2.12 *RF Radiation*

1) Characteristics (e.g., power levels, frequency, duration)

2) Locations (e.g., location of spacecraft when radiating, location of receivers)

3) Checkout Requirements (e.g., open-loop, closed-loop, prelaunch, and ascent trajectory)

2.3.3 Tug Interface Definition

2.3.3.1 *Mechanical Interfaces*

1) Mounting Points (e.g., location, number, size, type of mounting hardware)

2) Mounting Alignment (e.g., rotational and planar position requirements relative to local horizon)

3) Mounting Surface Characteristics (e.g., co-planarity, flatness)

4) Service Items (e.g., location, size, and type of commodity lines, special attachments)

5) Connector Details (e.g., manual, flyaway, umbilical, or in-orbiter operation)

6) Commodity Requirements (e.g., type, pressure, flow rate, temperature, quantity, timing)

2.3.3.2 *Electrical Interfaces*

1) Connector Items (i.e., location, function)

2) Connector Details (e.g., flyaway, umbilical, or in-orbiter operation; manufacturers part number; potting type; type of potting compound; wire size; pin assignment)

3) Bonding Requirements (e.g., interface materials, finishes)

4) Shielding Requirements (e.g., each conductor, entire connector, shield grounding, maximum shield ground length, shield ground through connector)

2.3.3.3 *Electrical Power*

1) 28-vdc Control Power (i.e., current, duration, function, time, tolerances)

2) 28-vdc Ordnance Power (i.e., current, duration, function, time, tolerances)

3) 28-vdc Instrumentation Power (i.e., current, duration, function, time, tolerances)

4) 10-vdc Instrumentation Power (i.e., current, duration, function, time, tolerances)

5) Overcurrent Protection Requirements

2.3.3.4 *Telemetry Transmission via Tug*

1) Identify Measurements (e.g., temperature, pressure, switch closure)

2) Signal Characteristics (i.e., discrete bilevel, analog, maximum response, sampling rate, condition represented by on-off or high-low state)

3) Signal Conditioning Requirements (e.g., input impedance, impedance circuit load limits, overcurrent protection, signal-to-noise ratio)

4) Identify Circuit (i.e., connector number, pin number, wire size)

5) Time of Use (i.e., during checkout, prelaunch, inflight)

2.3.3.5 *Tug Avionics*

1) Command Link

2) Monitor Link

3) Safety Monitors and Controls

2.3.3.6 Ordnance Safing/Arming

1) Identify Items (i.e., function, location)

2) Accessibility (e.g., direct access, remote circuitry, manual or automated activation)

3) Sequence (i.e., installation and removal times)

2.3.3.7 Material Requirements

1) Compatibility (e.g., finishes, electrolytic aspects, chemical)

2) Outgassing (e.g., constraints on nature and quantity of constituents)

2.3.3.8 Preflight Environment

1) Capability (e.g., cleanliness, temperature, relative humidity, air conditioning, and air impingement limits in each area from spacecraft delivery through countdown)

2) Monitoring and Verification

2.3.4 GSE/Facility

2.3.4.1 Spacecraft/Tug Integration

1) How Accomplished (i.e., sequence from attachment to Tug through mission separation)

2) Handling Equipment (e.g., description, who supplies and operates, when used, where stored)

3) Spacecraft Covers (e.g., description, who supplies and uses, when used, where stored)

4) Spatial Envelopes (e.g., dimensions and clearance for containers, handling equipment, and payload covers; work area available)

2.3.4.2 Spacecraft Checkout GSE

1) Use and Storage (i.e., identity, locations of use and storage)

2) Installation Criteria (e.g., weight, volume, tiedown requirements; who supplies, installs, operates, and removes; when supplied, installed, used, and removed; post-use disposition)

3) Compatibility (e.g., compatibility with range safety requirements and Tug/Orbiter propellants)

4) Space Requirements (i.e., work/operating space requirements)

2.3.4.3 *Preflight Environment Protection*

1) Equipment (i.e., identity, characteristics, and location of required environmental protection equipment)

2) Operation (i.e., who supplies, installs, operates, and removes; when supplied, installed, used and removed; post-use disposition)

2.3.4.4 *Spacecraft Access*

1) Mechanical Attachment (i.e., capability for direct access from delivery through attachment of the spacecraft to the Tug)

2) After Orbiter Installation (i.e., capability for direct access after payload is installed in the orbiter bay)

3) Countdown (i.e., capability for direct access during the countdown)

2.3.4.5 *Umbilicals*

1) Identify (i.e., function and location)

2) Source (e.g., Tug or Orbiter)

3) Support and Control (e.g., structural support requirements, retraction mechanisms)

4) Installation (e.g., when and by whom supplied and installed)

2.3.4.6 *Commodities*

1) Identity (e.g., quantity of gases, propellants, chilled water)

2) Source (e.g., supplied by Tug common services or Orbiter)

3) Timing (i.e., time that commodities are available and ex-[illegible]ted transfer-time duration)

2.3.4.7 *Electrical Power*

1) GSE Requirements (e.g., voltage and frequency limits, consumption characteristics of power at all processing facilities)

2) Facility Requirements (e.g., voltage and frequency limits, consumption characteristics of power at each processing facility)

2.3.4.8 RF Transmission

1) Antennas (i.e., function, location, physical characteristics, beamwidth, beam direction, and relationship to other antennas and receivers/transmitters)

2) Transmission (e.g., frequency, power)

3) Operation (e.g., nature of use, operating time requirements)

2.3.4.9 Monitors and Control

1) Signals (i.e., identity of monitor signals from spacecraft and/or GSE during readiness verification and countdown, and time that signals are to be monitored)

2) Transmission (e.g., via Tug telemetry, Orbiter telemetry, and landline)

3) Evaluation (e.g., location of data evaluation center, evaluation responsibility, measurement limits, go/no-go constraints)

4) Launch Process System (i.e., software requirements on LPS via Tug and/or Orbiter)

2.4 Facility and GSE

Data presented here should depict the common resources, facility areas and characteristics, and decriptive ground support equipment available for joint usage with the potential spacecraft. These data should be oriented toward identifying the existing resources for receiving and inspection, spacecraft maintenance, payload integration, payload interface verification, and special purpose equipment, such as the LPS computer support.

2.4.1 Payload Processing - These data should include the capabilities and characteristics of the facilities available to the potential spacecraft. This should be done by referencing the launch site accommodation handbook for Shuttle payloads.

2.4.2 Ground Support Equipment - This data should identify the integration GSE available to support Tug to spacecraft and Payload to Orbiter interface verification. Data should identify by type and quantity the GSE, such as cradles and adapters for mating the spacecraft; simulators available to verify electrical interfaces; and fit-check devices for verifying mechanical/structural interfaces. Software available and software required should be identified for each interface verification concept as well as the computers and terminals available.

2.5 *Launch Site Operations*

This section should be tailored to provide the minimum essential information for outlining the overall operations for the potential Tug user. Each subject should be evaluated for applicability regarding the content and format for all potential users. Details should be limited to that necessary for the implementing and planning processes within the payload participating organizations.

2.5.1 Flow Chart - These data should define Tug processing requirements on a functional system basis rather than purely a hardware basis. The flow chart should show correlation of hardware, computer programs, facility, personnel, and procedural interrelationships at the launch site. Time line data should be allocated to the Tug process function in their sequence of accomplishment to indicate constraints of reaction time, performance time, maintenance down-time, equipment and personnel utilization time.

2.5.2 Restrictions - Restrictions that the potential user would be required to adhere to while at the launch site would be those normally imposed by others and would not be negotiable by the payload. These restrictions should include, but not be limited to, launch site activity limitations, constraints on payload operations in the Orbiter cargo bay, security requirements, personnel access limitation, safety precautions, and similar type of information. For DOD payloads, it may be more desirable to reference the appropriate document that specifies security precautions essential for the protection of personnel and maintenance of the integrity of the payload and the operation.

2.5.3 Flight Readiness Criteria - This paragraph should define the pre-established process of reducing technical risks and establishing confidence that the Tug/spacecraft is flight worthy. This information must clearly delineate selected tests, values to be measured versus pre-established criteria, and major milestones to be accomplished from which to judge results.

2.5.4 Countdown - Data presented here would specify the operations flow for conducting the launch countdown including any pertinent pre-countdown preparations. These data should include, as a minimum, the time-sequence of operations, responsibilities, operations control, and the step-by-step operations.

2.6 *Operations Management*

This paragraph should provide the minimum essential information for outlining the overall site management that involves the potential user. These data should include the established allocation of resources, scheduling of tasks, and assignments of authority

and responsibility. This information should be limited to the basic mode of Tug/spacecraft ground flow processing at the launch site.

2.6.1 Roles and Responsibilities - This paragraph should define the management and technical roles and responsibilities of each government and contractor agency with which the payload user would interface. These data should include the ground processing crew providing a hardware and/or software turnover is required.

This section involves standard role/responsibilities. Unique agreements for each spacecraft would be documented in an addendum.

2.6.2 Launch Site Management - This paragraph would delineate the day-to-day operations such as daily scheduling and status meetings that require payload participation. These data should include the duties of the mission manager who exercises final authority over conduct of integrated tests and launch operations. Individual elements that require test controllers/conductors that are responsive to the direction of the mission manager should be specified. All working groups that require payload participation to resolve problems that would affect Orbiter schedules and/or objectives as well as their interrelationships should be defined.

2.6.3 Launch Site Documentation - This paragraph defines the documentation for the payload, after Tug/spacecraft mate, to be processed at the launch site. These data should include, as a minimum, all documentation required, and assigned preparation responsibilities and release dates as required. Documentation herein is construed to include all operations and flight plans, integrated test plans, operation schedules, integrated test procedures, and range required documentation.

2.6.4 Operations and Support - This paragraph defines what activities are necessary to demonstrate to the appropriate control that the payload (Tug/spacecraft) is ready for STS integration. These data should define the readiness reviews required to verify successful completion of all prerequisite tests and operations, and readiness to proceed with subsequent activities. Post-test and launch evaluation criteria and reporting responsibilities would be specified at the element level. Payload required participation to support the product review team to conduct an in-depth engineering assessment of all STS elements and associated ground support equipment, including physical inspections of the hardware, review of associated documentation and test data would be delineated. Payload participation in the existing test discipline system should be specified, such as (1) integrity control to prevent unauthorized work or tampering, and (2) test anomalies reaction to a hold, scrub, or recycle.

3.0 Spacecraft Essential Data

Spacecraft essential data should be determined by requiring the spacecraft project to answer a questionnaire. The questionnaire would use each paragraph of 2.3, *Tug Payload Accommodations and Constraints*, and description of what portion of the Tug capabilities the spacecraft would require. If spacecraft requirements are marginal or exceed Tug capabilities, these requirements would then be negotiated and results documented in the addendum for that mission. The questionnaire is mandatory for the Payload Integration Agency to perform the integration tasks.

4.0 Addendum

The addendum should be prepared on a per mission basis. It should contain only those requirements/agreement unique to this spacecraft and not cover the standard user's guide. This could be accomplished by writing the user's guide addendum by direct reference to the standard user's guide on a paragraph-by-paragraph basis, recording in the addendum specific deltas to paragraphs in the standard user's guide. Where no change is necessary specify the paragraph number followed by the wording "no change". When no subparagraphs are changed, only the related major paragraphs need be listed.

This addendum plus the standard user's guide would then become the integration agreement document depicting physical and functional interface requirements that affect the design or operation of the Tug and/or its payload. This addendum could be used as design control document, delineating interface coordinated data for the purpose of (1) establishing and maintaining compatibility between the Tug and its user, (2) controlling interface designs, thereby minimizing changes to items that would adversely affect compatibility, (3) communicating design decisions and changes to participating agencies, (4) establishing envelope and access compatibility to verify that all interface agencies supplied equipment/facilities can function without interference through all expected ground processing, and (5) containing standard interface controls.

The agreements created by the addendum and the basic user's guide could have independent change cycles. A change notice to either would not necessarily be a change to both.

CONTENTS

Table

D. TUG SITE ACTIVATION PHASE SUBPLAN

PART I - CLEAN TUG PROCESSING

1.0 Introduction

At the onset of our study, it was generally assumed that the Tug would be processed in a class 100,000 clean room. Task 1.0 (subplan A) reflects the requirement for processing in a clean facility. Subsequently, we analyzed the possibility of processing in a "factory clean" environment in Task 10.0 (Addendum 6). As a result of that analysis, we recommend "factory clean" processing using the VAB low bay. However, since class 100,000 clean processing and factory clean processing are viable options, we have covered both in this subplan.

Part I provides a top level plan for the activation of a KSC facility for processing of Tug in a class 100,000 clean environment, and the activation approach for the processing flow described in subplan A. Part II of this subplan provides a similar plan for activation of a KSC facility for Tug processing in a factory clean environment, and the activation plan for the factory clean processing flow presented in Addendum 6.

This Tug Activation Phase Subplan for class 100,000 clean Tug processing describes the scope of effort required to provide operational Tug capability at ETR and WTR. This plan is keyed to Tug processing in the TPF with spacecraft mate in the user's facility (Option 2 presented in subplan E). The activation phase encompasses the period from development of facility and GSE criteria through launch of the first flight article and includes the following major activities.

1) Development of facility and GSE criteria;
2) Facility and GSE design;
3) Facility and GSE construction;
4) Facility and GSE validation;
5) Functional verification using a prototype Tug;
6) Checkout and launch of the first flight Tug.

These activities are described in Section 3.0. Related supporting functions such as manpower staffing, safety, software development, logistics, and configuration management are also covered in Section 3.0.

In the interest of clarity and to avoid repetition, Section 3.0 follows the "single option" criterion when describing facility sites, methods of operations, and flow sequences. Recognizing that in many cases alternatives are available, Section 4.0 of the subplan is devoted to describing and assessing the merits of such alternatives.

2.0 General Requirements

2.1 *Ground Rules*

The basic ground rules adopted for this section of the study follow.

1) Operational Tug launch capability would be provided at both ETR and WTR, however, WTR would have limited maintenance and checkout capability.

2) A Tug processing facility would be provided at ETR only to service both ETR and WTR. Tugs will be ferried to WTR after turnaround processing at ETR.

3) Tug processing and spacecraft mating would be performed in a class 100,000 environment.

4) Existing facilities and equipment would be used to the utmost.

5) Existing facilities and equipment selected would be available during the site activation phase.

6) Tug processing, mating, and transport after spacecraft mating would be performed with Tug in vertical position.

7) An engineering model Tug would be available for functional checkout of the new/modified facilities, if required.

8) An Orbiter vehicle would be made available at the launch complex for mating/checkout/loading of the engineering model Tug.

2.2 *Criteria and Standards*

Criteria governing site selection, GSE requirements, modifications, and modes of operation are based on NASA Tug program requirements, NASA and USAF documents, standards, and drawings, other current government standards, industry standards and codes.

2.2.1 <u>NASA Program Requirements</u> -

1) MSFC 68M00039-1, 15 July 1974, Baseline Space Tug System Requirements and Guidelines.

2) MSFC 68M00039-3, 15 July 1974, Baseline Space Tug Configuration Definition.

3) MSFC 68M00039-4, 15 July 1974, Baseline Space Tug Ground Operations: Verification, Analysis and Processing.

2.2.2 NASA and USAF Documents and Drawings -

1) NASA - SAEF #1 Dwg 79K02468, Alternate Airlock Dwg 79K02820

2) NASA - Modifications to LC-39A, Dwg 79K04402 (60%)

3) NASA - LC39 Vertical Assembly Bldg, Dwg 203-100 (Vol 15 and 27)

4) NASA - Support Services Handbook, KHB8610.1A/AD

5) NASA - Merritt Island Industrial Area, Facilities Space Control Document, GP680

6) Launch Complex 39, Facilities Space Control Document (not numbered)

7) KSC Safety Program, KMI1710.1B and Attachment A, KSC General Safety Plan

8) USAF - AFETRM 127-1, Range Safety Manual

2.2.3 Government/Industry and Standards -

1) FED STD No. 209 - Clean Room and Work Station Requirements, Controlled Environment

2) MIL-STD-1246A - Product Cleanliness Levels and Contamination Control Program

3) National Electrical Code, 1971

3.0 Site Activation Phase Study Elements

This study requires that 12 standard study elements be treated in each subplan. Not all of these are applicable to each subplan. Each element is shown under the same paragraph number in every subplan. Paragraphs 3.1 through 3.12 represent these standard study elements. The order in which subjects are treated are not necessarily chronological; therefore, they do not reflect the sequence in which the described activities would occur.

3.1 Ground Operational Flow

3.1.1 Engineering Model Flow - A Tug engineering model will be used at ETR before arrival of the first flight article. The primary objective of the engineering model will be to verify GSE interface with the Tug; however, the total intent will be to:

1) determine, document, and resolve GSE/Facility/Tug interface problems, electrical, mechanical, and structural;

2) verify accuracy and completeness of Tug operational procedures;

3) verify accuracy and completeness of LPS control and monitoring software programs;

4) train personnel;

5) determine compatibility of Tug/Orbiter interfaces;

6) determine Tug/Adapter/kick stage/spacecraft interface compatibility;

7) develop procedures, methods, and hardware to minimize Tug flow time for all planned and contingency functions;

8) verify logistic approaches of transportation in a canister and airborne site-to-site shipment compatibility.

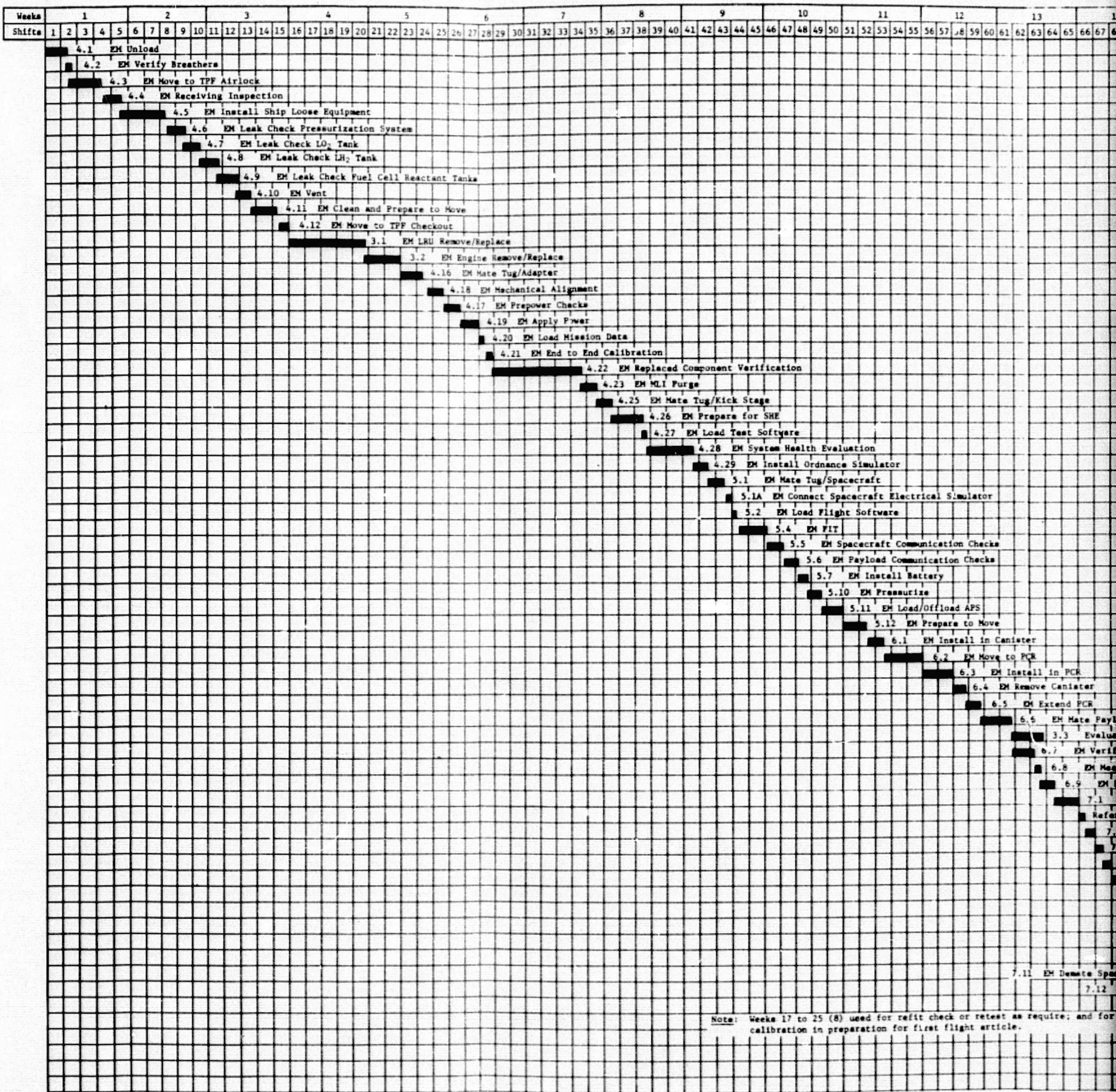
The engineering model flow depicted in Figure III-D-1 has been developed using the following assumptions and ground rules:

1) The model will be as functionally complete as a flight Tug. It is recommended that the Structural Test Article (STA) or Propulsion Test Vehicle (PTV), if available, be evaluated for suitability in terms of capability and schedule. If either, or a combination of both, could be used for site activation, a significant cost savings could be realized.

2) The flow time for each function depicts the time required to perform that function for the first time, including minor problem correction. It does not include time for any major problem resolution that could include major procedure rewrite, major redesign, material leadtime, etc.

3) The engineering model flow will follow the planned Tug operational flow as closely as possible.

4) Major interface functions such as countdown demonstration will not be performed in their entirety, but any Payload/Orbiter interface functions will be performed completely.



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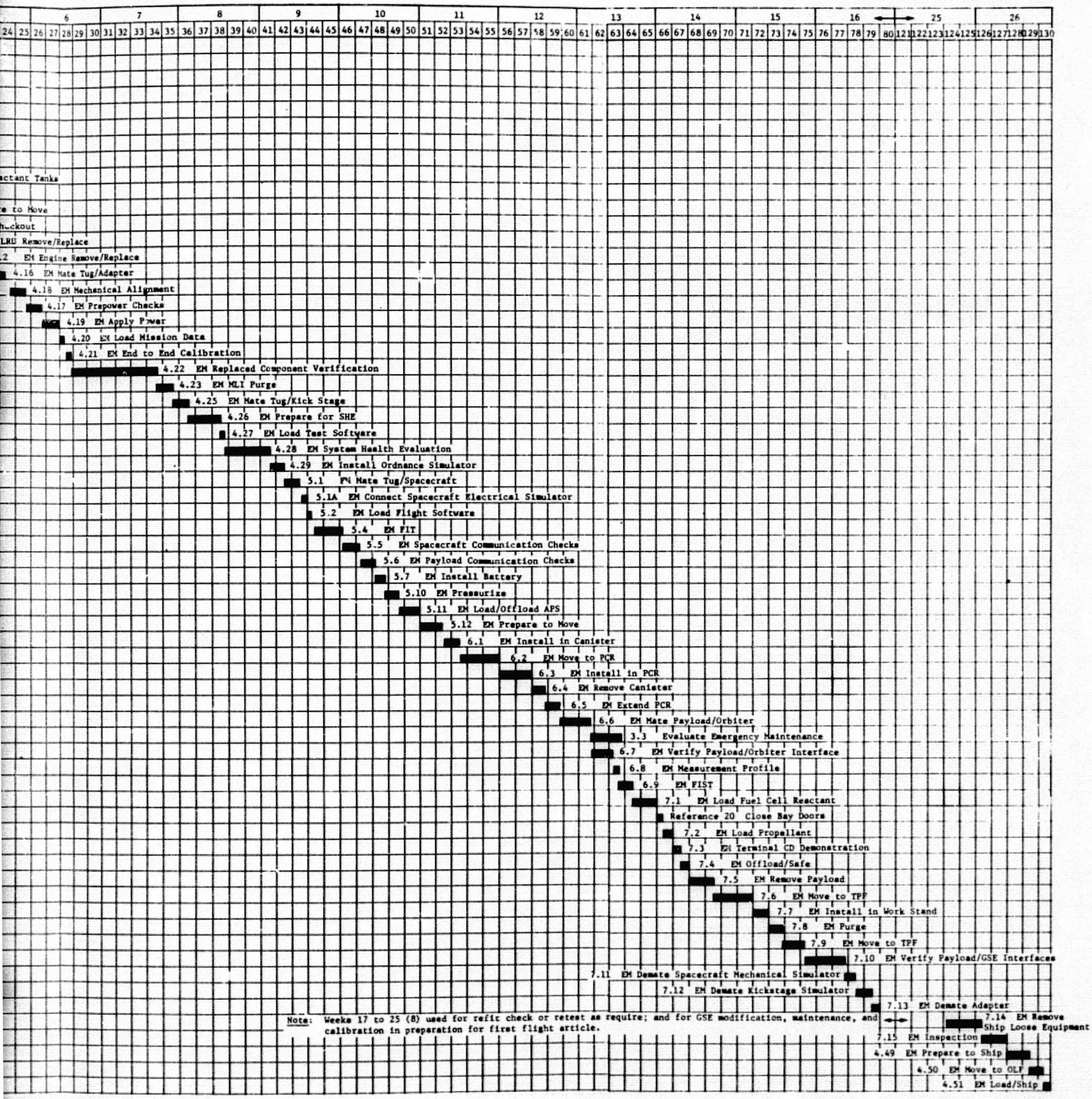

Figure III-D-1 Engineering Model Flow

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5) Tug operational procedures and LPS control and monitor software programs will be prepared by the start of engineering model flow.

6) LPS program control of GSE will have been verified during the ground system test phase, but for safety of personnel and protection of GSE and model hardware, this GSE will be locally monitored during the engineering model flow.

7) The engineering model flow is based on a one-shift/five-day week to reduce manpower requirements and afford the capability of cross-training personnel.

8) Facility support requirements for each function have been identified before the start of flow (personnel, type and amount of commodities, range frequencies, sampling, etc).

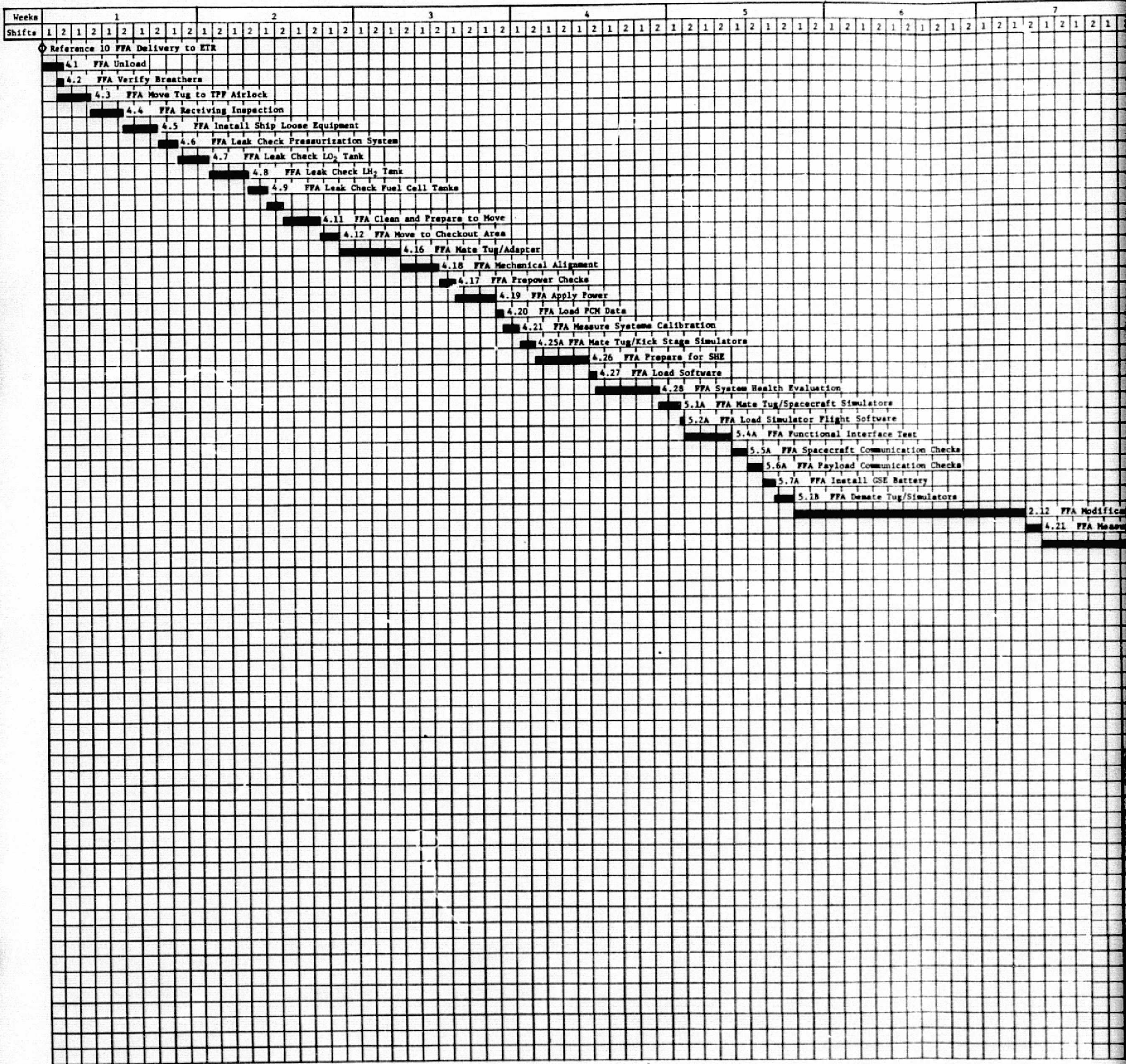
9) The Shuttle/Orbiter operation involving the PCR, Orbiter to ground interfaces, etc, have been operational.

The flow of the engineering model and the first flight article will follow the same steps of the processing shown in subplan A. Function description sheets are provided in Appendix A. The operation numbers shown in Figure III-D-1, i.e. 4.1, 4.2, etc, provide cross reference to the detailed function description sheets in Appendix A. Where there is a difference between the processing of an operational Tug and the engineering model, an engineering model description sheet is provided in Appendix A.

3.1.2 First Flight Article Flow - The first flight article Tug will be used somewhat in the same manner as the engineering model. A major assumption is that the first flight article (FFA) will be delivered to ETR 90 days before launch to provide time for problem resolution if necessary.

The first flight article flow (Fig. III-D-2) was established on the basis of 12 weeks total flow using five-day work weeks of two shifts per day. As described in the Function Description Data Sheets included in Appendix A, the FFA will be processed through the planned TPF operations using kick stage and spacecraft simulators, when required, to provide total system simulations.

It is assumed that major problems concerning GSE, procedures, methods, and flight hardware interfaces will have been resolved during the flow of the engineering model. However, the objectives of the proposed FFA flow are to reverify with flight hardware, that all software, GSE, and operational methods are compatible, to attain minimum flight article turnaround flow time.



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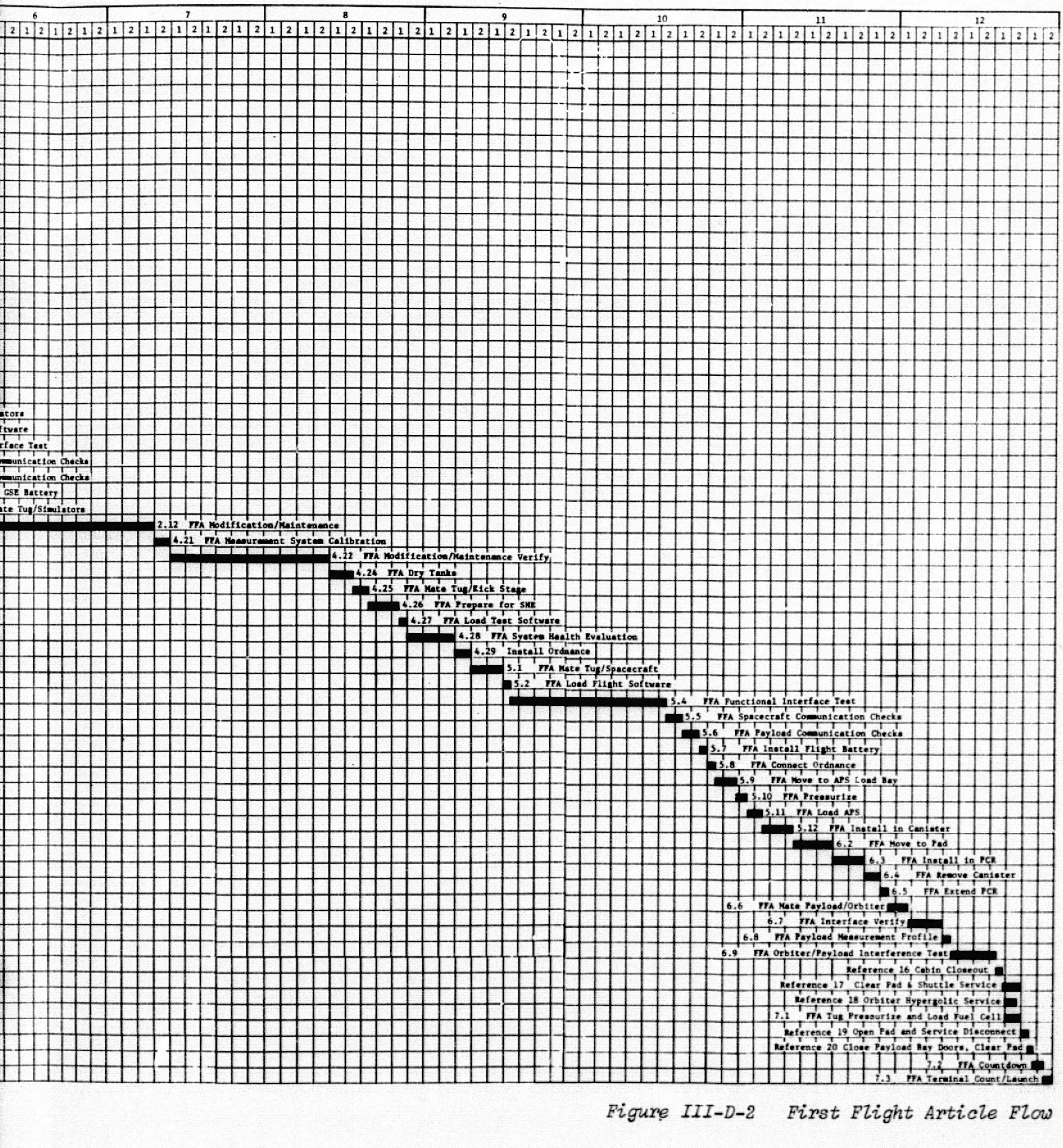


Figure III-D-2 First Flight Article Flow

3.1.3 Critical Milestones - Assuming the first Tug launch to be December 1983 and a Tug launch site modification go-ahead in January 1980, the critical dates or milestones for KSC activities follow.

Sites

TPF available for modification	December 1980
OPF available for modification	April 1981
PCR/PAD available for modification	February 1981
TPF ready for engineering model checkout	February 1983
PCR/PAD ready for engineering model checkout	April 1983
OPF ready for engineering model checkout	June 1983

Equipment

Engineering model at KSC	February 1983
Dummy spacecraft and kick stage at KSC	February 1983
Canister/transporter available	April 1983
Orbiter available on pad for engineering model checkout	April 1983
First flight Tug onsite	September 1983
Spacecraft and kick stage ready for mate	November 1983

3.2 Facility and GSE Requirements Specification

3.2.1 Facility - New and Modified

3.2.1.1 General - The new and modified facilities identified in this study include:

1) TPF SAEF-1 - An existing class 100,000 clean building and support facilities at KSC, modified to provide the Tug Processing Facility by:

    a) Increasing the height of the existing airlock from 68 ft (21 m) to 105 ft (32 m) to accommodate a mated Tug/spacecraft in the vertical position and permit insertion into the transport canister.

b) Addition of two Tug checkout stands of 35x25 ft (10.8x7.7 m).

c) Provision of a 25x25 ft (7.7x7.7 m) area for IUS processing.

d) Provision of an engine checkout area of 25x24 ft (7.7x7.4 m).

e) Reallocation of existing office, lab, and shop space for Tug usage.

f) Addition of an H_2/N_2H_4 burnstack no less than 200 ft (61 m) from the building with associated piping.

Figure III-D-3 depicts the external configuration of SAEF-1 after the airlock modification raises the airlock roof to accommodate the canister. Figure III-D-4 depicts the SAEF-1 floor plan after modification to the TPF configuration. Several internal configurations or layouts have been evaluated; this approach has been selected as the best because of Tug and Tug/spacecraft handling and movement considerations and refurbish-checkout cell location.

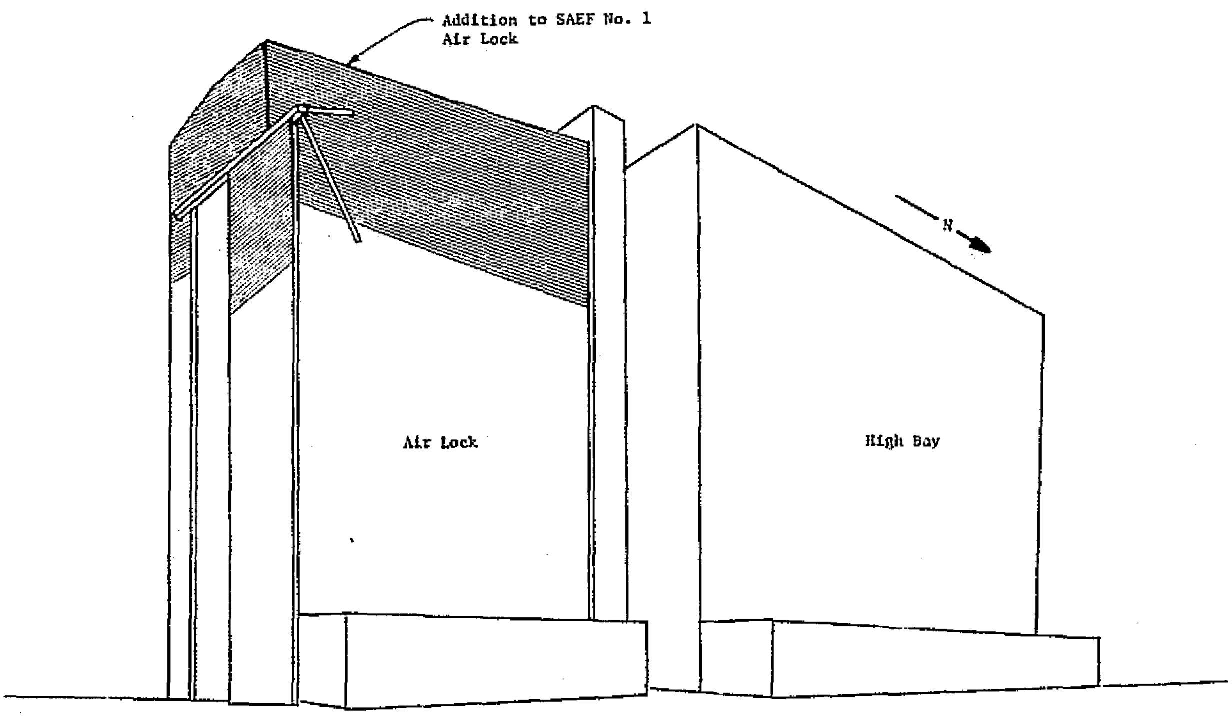


Figure III-D-3 SAEF-1 TPF, View

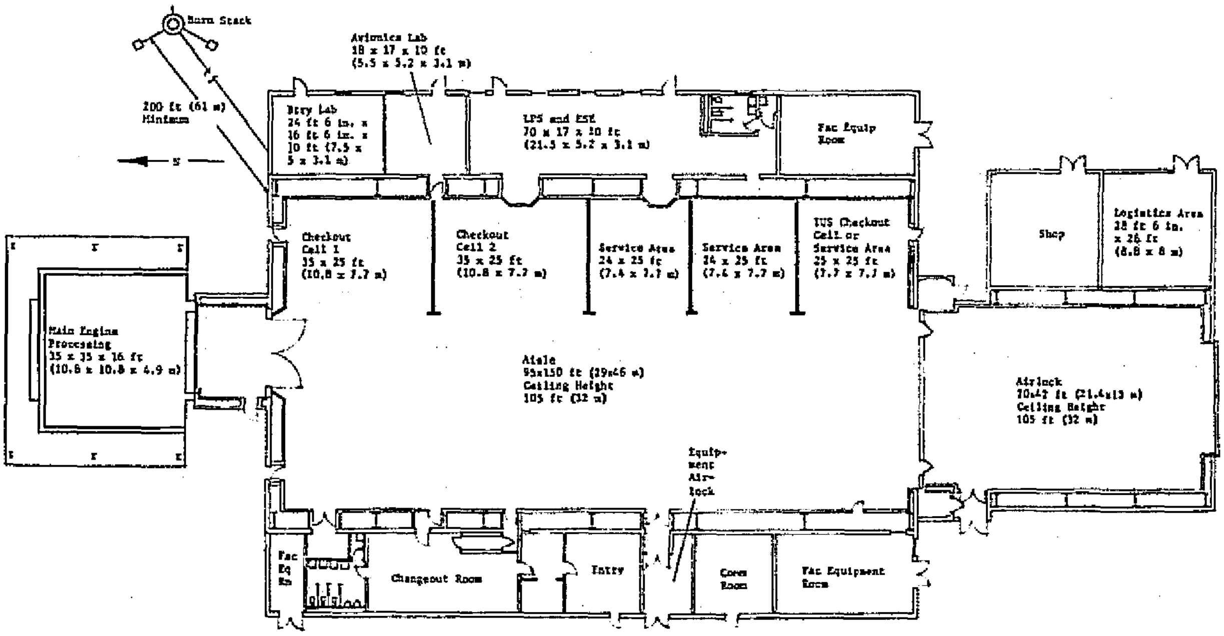


Figure III-D-4 SAEF-1 TPF Floor Plan

The VAB low bay area was evaluated as a site for clean Tug processing; however, the modification costs to make the low bay refurbish/checkout cells a class 100,000 clean area were greater than modifying the SAEF-1 to accommodate the Tug, i.e., $19.3 million for VAB vs $18.4 million for SAEF-1. Therefore, the VAB low bay was dropped from further consideration early in the evaluation.

2) Storage and Maintenance Building - A new building approximately 140x75x30 ft high (43x23x9.2 m), containing the main Tug operations office area, a maintenance shop area, and an environmentally controlled bonded storage area. Paved areas for access and parking would be required. The building would be located west of SAEF-1 and as near as safety requirements permit. This building, together with SAEF-1, would provide a completely self-contained Tug processing facility. Figure III-D-5 shows the overall TPF area layout.

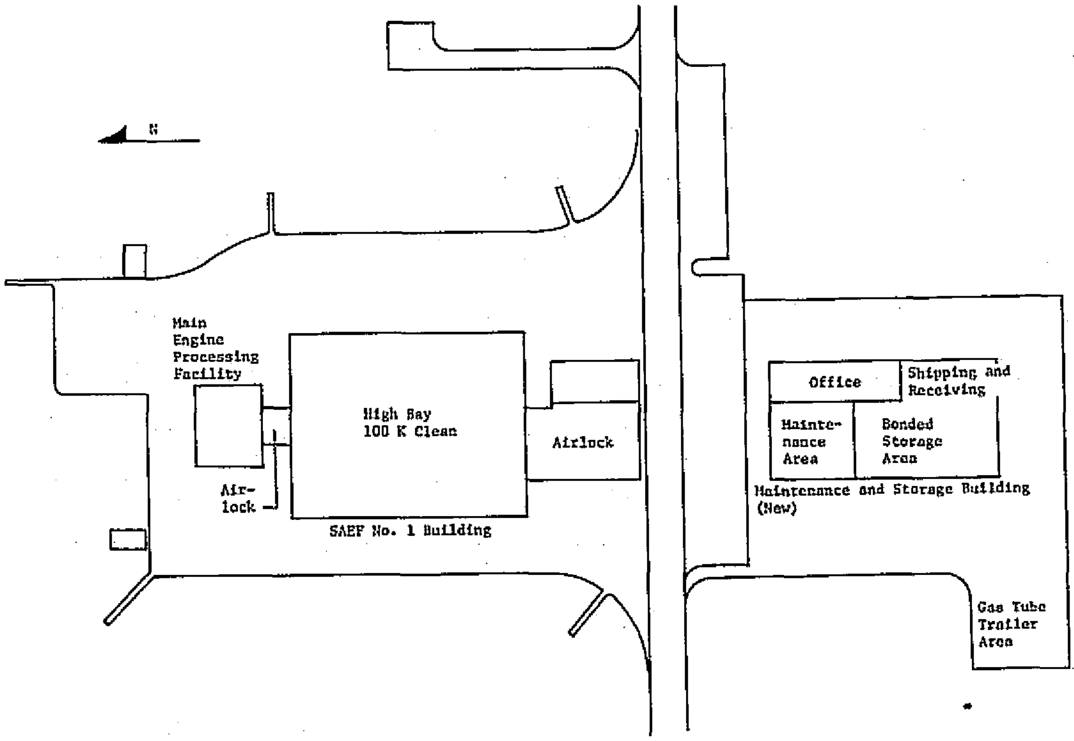


Figure III-D-5 TPF Area Plan

ORIGINAL PAGE IS
OF POOR QUALITY

3) Launch Complex 39A - The principal modifications to LC39A to accommodate the full Space Tug/spacecraft/kick stage combination would include the following:

   a) Modification/adjustment of PCR platforms to accommodate Tug/spacecraft diameters and work stations;

   b) Modification/adjustment of the PCR manipulator for Tug diameter and hard point locations;

   c) Modification of existing LH_2 and LO_2 piping to interface with new GSE Tug LH_2/LO_2 propellant loading units;

   d) Addition/modification of LPS interfaces for Tug requirements;

   e) Provision of electrical interfaces at the LCC for GSE Tug monitoring and propellant loading consoles.

   It is assumed that the PCR has been constructed and in use for the IUS program, and that an IUS-to-Orbiter insertion manipulator is in existence.

4) Kick Stage Processing Facility - An existing facility (to be determined) for processing the solid rocket motor kick stage. Facilities under consideration include:

   a) Explosive Safe Area-60-A (CKAFS)

   b) The TIIIC SRM Facility (CKAFS)

   Peculiar handling equipment would be provided as GSE. Existing electrical/pneumatic sources would accommodate kick stage requirements using GSE adapters.

5) Orbiter Processing Facility - The existing facility being developed for Shuttle postflight processing should include these Tug peculiar requirements:

   a) An 8 ton (7260 kg) overhead crane capability;

   b) 150x60 ft (46x18.3 m) floor area;

c) Storage and maintenance area;

d) Eye washers and showers;

e) Added/relocated electrical outlets and pneumatic connections;

f) Office and crew space.

Tank purge, propellant disposal, and Tug/spacecraft handling equipment would be furnished as GSE.

6) Spacecraft Processing Facilities - Any facility modification requirements to the existing facilities at CKAFS and KSC where NASA and DOD spacecraft are processed at present will depend on individual spacecraft requirements. These include buildings AO, AM, AE, SAB (at CKAFS) and the O&C building and SAEF-2 (MILA Industrial Area). Additional facilities may be required depending upon spececraft launch rate and launch preparation/checkout time.

7) WTR Facilities - With the Tug Processing Facility at ETR only, the new/modified WTR facilities required to support Tug operations would include the following:

a) OPF - Modified to provide crane support, Tug-peculiar commodities, office, crew, shop, and storage space.

b) PCR/Pad SLC-6 - Modified to provide propellant and pneumatic interfaces for the GSE LH_2 and LO_2 loading units and LPS interfaces; platform modifications/adjustments for Tug diameter and working stations; modification/adjustment of the PCR manipulator to accommodate Tug hard points; addition of electrical interfaces in the Control Center for Tug monitor and loading consoles.

c) Payload Processing Facility (PPF) - A facility modified to accept Tug and Tug GSE for Tug systems and Tug/spacecraft integrated checkout.

3.2.1.2 *Tug Facility Requirements Specification Data Sheets* - The new/modified facilities requirements are described in detail in the Tug Facility Requirements Specification Data Sheets contained in Appendix D.

3.2.2 GSE - The new/modified operational GSE to be used during Tug site activation will include:

1) avionics checkout and monitoring equipment;

2) handling, access, and transportation equipment;

3) propulsion, pneumatic, and mechanical checkout and servicing equipment;

4) structural integrity inspection equipment.

The Tug GSE required is identified and described in detail in the Tug GSE specification data sheets contained in Appendix B.

3.3 Transporation Requirements and Support

3.3.1 Tug Canister/Transporter - The canister/transporter concept developed in previous studies could be used on the Tug program. Figure III-D-6 shows one proposed design for this equipment.

Should the equipment final design evolve a universal canister/transporter, then adaptation for Tug would involve only adjustment of the internal mounting hard points to accommodate the Tug diameter and hard point locations. If the universal concept proves impractical, the basic requirements for Tug would be:

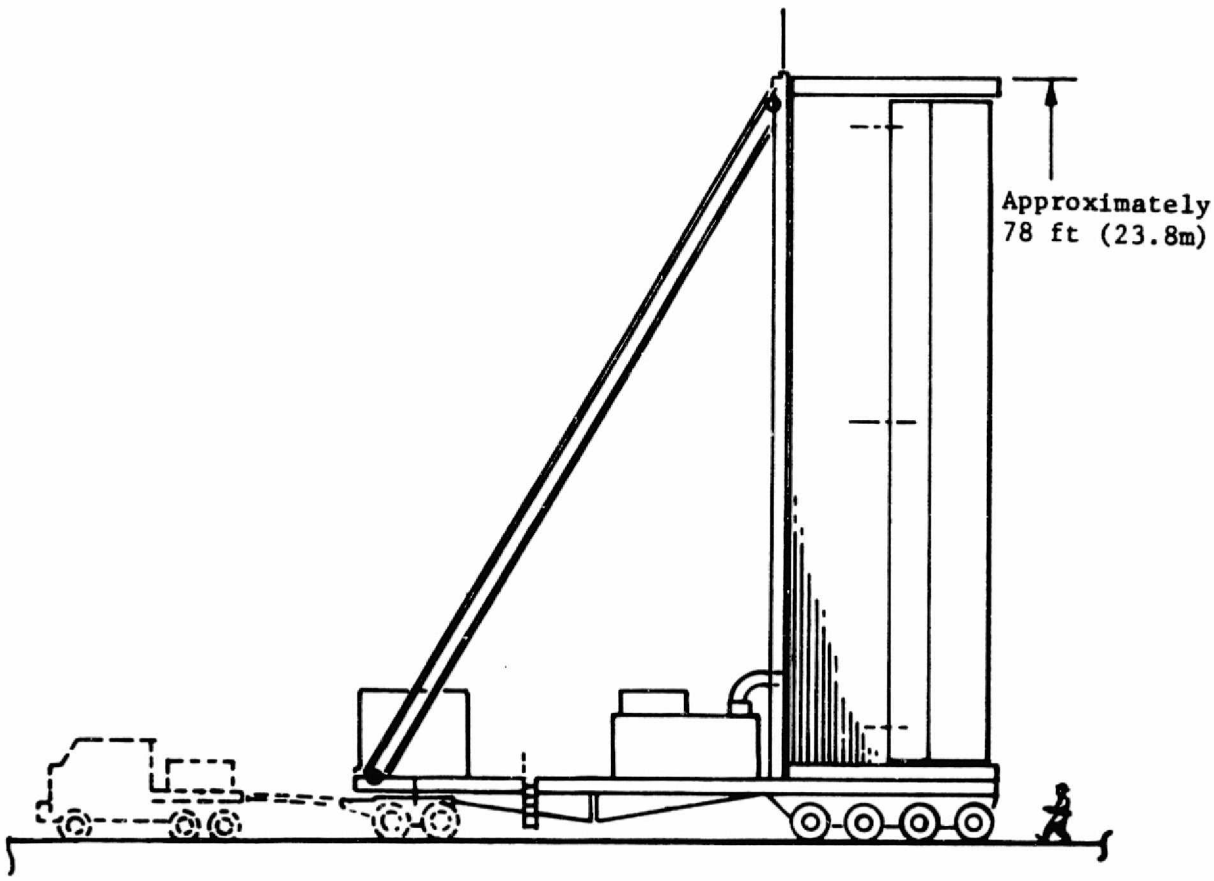
1) capability of housing a 14.6 ft (4.9 m) diameter by 60 ft (18.3 m) length payload that could consist of Tug/kick stage/spacecraft or other configurations, in a vertical position;

2) environmental control of the canister during transportation;

3) swing-open door entry into the canister;

4) capability of sealing the entrance against the TPF door opening and at the PCR;

5) self-leveling of the transporter during ascent of the launch pad ramp at ETR.



A Vertical Payload
Transporter

Figure III-D-6 Conceptual Canister/Transporter

3.3.2 Tug Transportation - The Tug-peculiar transportation requirements are described in detail in the GSE Requirement Specification Data Sheets in Appendix B. These requirements can be summarized as follows:

1) Tug transtainer for transport to and from the aircraft, with provision for maintaining a clean environment when shipping a checked out Tug from ETR to WTR.

2) Kick stage transtainer.

3) Spacecraft transport vehicle (provided as a spacecraft peculiar requirement by the spacecraft agency).

4) TPF Tug manipulator. Although considered as handling equipment, the conceptual design (Fig. III-D-7) indicates it would be a self-propelled wheeled vehicle capable of being used at several locations at ETR as required. The existing 50 ton (45,360 kg) fork lift currently in the KSC inventory could be modified to meet Tug requirements.

Transportation of the Tug and major ship separate subassemblies from the supplier to ETR will be by air, with the Tug in the horizontal position. There are no Tug requirements for keeping the Tug verticial position during transport or checkout.

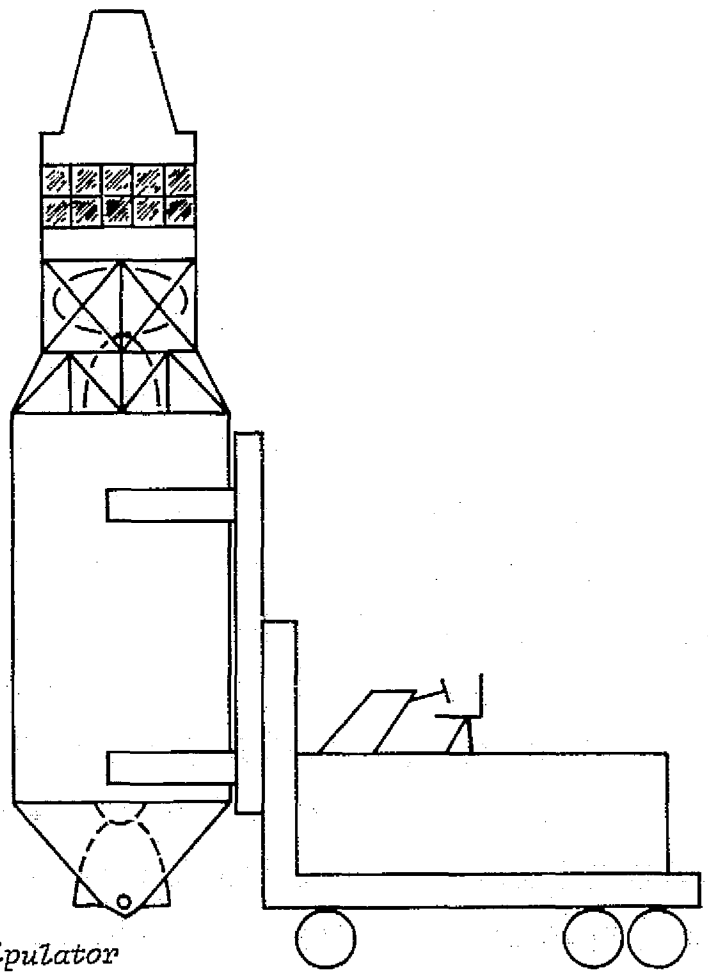


Figure III-D-7 TPF Manipulator

3.4 Operational Data Requirements

Not applicable to site activation phase subplan

3.5 Manpower Staffing

The Tug site activation phase can be dividied as follows:

1) Planning, design, and construction;

2) Facility/GSE verification with a Tug engineering model;

3) Processing, checkout, and launch of the first flight article.

The manpower staffing during the activation period is based on the requirements through these phases, resulting in gradual buildup from a skeleton force to a full operational crew.

For purposes of organizational responsibility, the activation phase essentially consists of a facility/GSE construction period and a vehicle utilization period. The construction period covers activities from facility/GSE criteria development through construction, and validation of the facility/GSE installations. The proposed organization during the construction period for ETR is shown in Figure III-D-8. The manpower buildup during

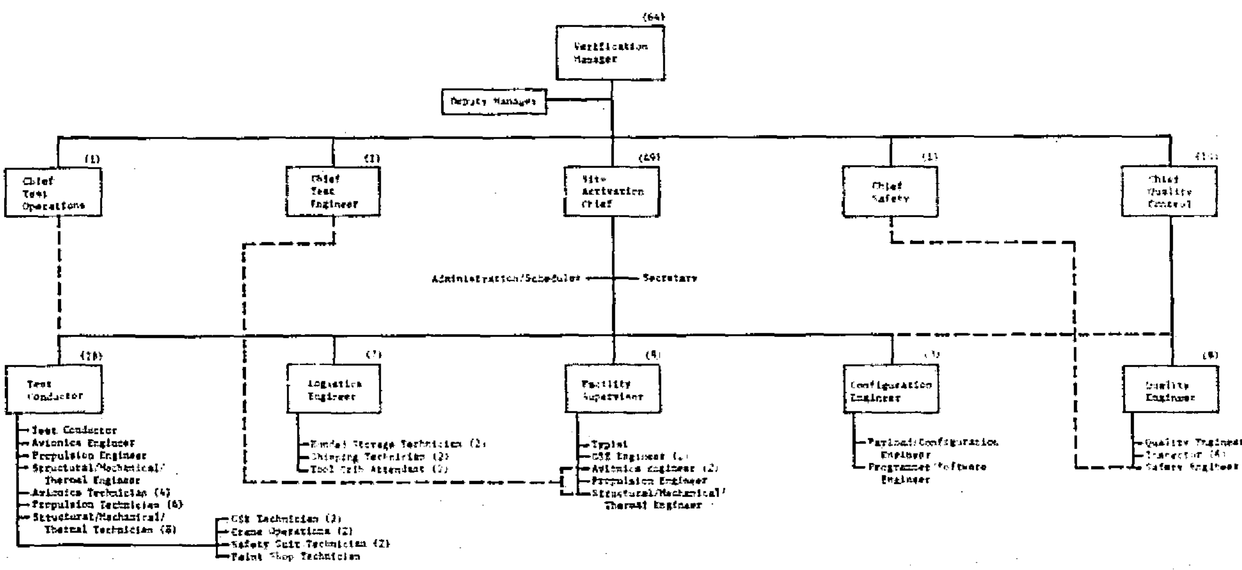


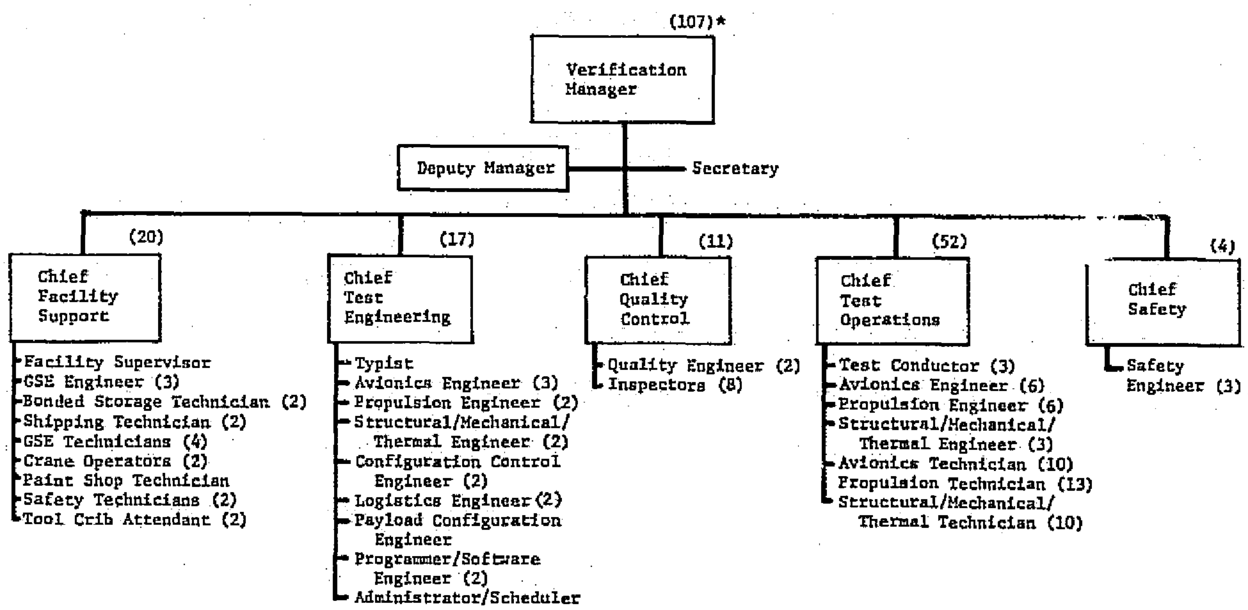
Figure III-D-8 ETR Site Activation, Construction Crew Size

Manpower Control

	1980												1981												1982											
Description	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Activation Chief	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administration/Scheduler	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Secretary/Typist	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Facility Supervisor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2	2	2	2	2	2	4	4	4	4	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Test Conductor							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
Engineers							1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Technicians																			2	2	2	3	3	3	11	11	11	22	22	22	23	23	23	23	23	23
Logistics Engineer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technicians							1	1	1	1	1	2	2	2	2	2	2	2	4	4	4	4	4	4	5	5	5	6	6	6	6	6	6	6	6	6
Configuration Engineer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers							1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Quality Control Chief	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers				1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Inspectors							1	1	1	1	1	2	2	2	2	2	2	2	4	4	4	4	4	4	5	5	5	6	6	6	6	6	6	6	6	6
Subtotal	9	9	9	10	10	10	19	19	19	19	19	23	23	23	23	23	23	23	32	32	32	34	34	34	45	45	45	58	58	58	59	59	59	59	59	59
Verification Manager	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Deputy Manager												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chief Test Operations																									1	1	1	1	1	1	1	1	1	1	1	1
Chief Test Engineering												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chief Safety																									1	1	1	1	1	1	1	1	1	1	1	1
Subtotal	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	5	5
Total	10	10	10	11	11	11	20	20	20	20	20	26	26	26	26	26	26	26	35	35	35	37	37	37	50	50	50	63	63	63	64	64	64	64	64	64

Figure III-D-9 ETR Site Activation, Construction Period

The transition to the vehicle utilization period will occur on completion of the construction/installation validation effort. It is anticipated that the transition will be smooth because personnel used in the first period will now have support functions in the second period. The proposed organization during the vehicle utilization period at ETR is shown in Figure III-D-10. The detailed manpower buildup during this period (through launch of the first flight article) is shown in Figure III-D-11.



*Includes WIR Support Personnel

Figure III-D-10 ETR Launch Site Operations Crew Size

3.6 Safety Requirements and Support

The potential for accidents/incidents is normally high during construction, installation, and initial operation activities. This potential may be reduced by application of safety requirements and support during the entire site activation phase. System safety activities during the site activation phase are divided into the two distinct but interrelated types discussed in the following paragraphs.

Manpower Control																								
	1982												1983											
Description	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Verification Manager													1	1	1	1	1	1	1	1	1	1	1	1
Deputy Manager													1	1	1	1	1	1	1	1	1	1	1	1
Secretary/Typist													2	2	2	2	2	2	2	2	2	2	2	2
Chief Facility Support													1	1	1	1	1	1	1	1	1	1	1	1
Facility Supervisor													1	1	1	1	1	1	1	1	1	1	1	1
Engineers													2	2	2	2	2	2	2	3	3	3	3	3
Technicians													13	13	13	13	13	13	13	15	15	15	15	15
Chief Test Engineering													1	1	1	1	1	1	1	1	1	1	1	1
Engineers													7	7	7	7	7	7	7	14	14	14	14	14
Administrator/Scheduler													1	1	1	1	1	1	1	1	1	1	1	1
Chief Quality Control													1	1	1	1	1	1	1	1	1	1	1	1
Quality Engineers													2	2	2	2	2	2	2	2	2	2	2	2
Inspectors													6	6	6	6	6	6	6	8	8	8	8	8
Chief Test Operations													1	1	1	1	1	1	1	1	1	1	1	1
Test Conductor													2	2	2	2	2	2	2	3	3	3	3	3
Engineers	4	4	4	4	4	4	4	4	4	4	4	4	8	11	11	11	11	11	11	15	15	15	15	15
Technicians													16	24	24	24	24	24	24	33	33	33	33	33
Chief Safety													1	1	1	1	1	1	1	1	1	1	1	1
Safety Engineers													1	2	2	2	2	2	2	3	3	3	3	3
Total	4	4	4	4	4	4	4	4	4	4	4	4	68	80	80	80	80	80	80	107	107	107	107	107

Figure III-D-11 ETR Site Activation, Engineering Model and First Flight Article

3.6.1 Facility/GSE Design - The responsible agency must ensure that system safety requirements are included in all design criteria. Active participation by qualified safety engineers in the criteria and design development is a basic requirement to assure compliance with agency, program, and Occupational Safety and Health Act (OSHA) regulations, and detail requirements. System safety participation in the established reviews of facility/GSE designs is also required to ensure compliance with the safety criteria.

3.6.2 Validation and Initial Operations - The activities of facility construction/GSE installation, validation, functional checkout with an engineering model Tug, and first flight article processing are common to site (field) operations. Sound protective measures in the field are implemented by an aggressive accident/incident prevention effort, as follows:

1) Develop and enforce a Safety and Health Program consistent with KSC safety requirements contained in KMI 17101B/SF. The program will include, but not be limited to, all contractually related safety documents and applicable criteria obtained from other areas or agencies.

2) Establish criteria for and implement Safety and Health education programs for personnel.

3) Make regularly scheduled evaluations of all work areas to determine the need for safety and industrial hygiene improvements, initiate corrective action, and follow through to eliminate discrepancies.

4) Ensure that all operations are performed in accordance with applicable Federal, State, KSC and ETR safety requirements and provide liaison to agencies as required.

5) Prepare special Safety Operating Procedures and coordinate with responsible agencies to obtain approvals.

6) Prepare and distribute Safety Information Bulletins to describe new requirements, techniques, and products.

7) Establish, certify, and enforce requirements for standard or specialized safety equipment, including protective clothing, to protect personnel from inherent hazards.

8) Monitor all hazardous operations to ensure no deviation from approved safety practices.

9) Review test procedures, procedure change notices, maintenance procedures, test orders, and standard operating procedures, to ensure approval and inclusion of safety requirements.

10) Provide an Industrial Safety Program in accordance with KSC requirements.

11) Investigate all accidents and incidents. Prepare and submit reports as applicable.

3.7 Fleet Utilization and IUS/Tug-to-Payload Integration Requirements

Not applicable to this subplan.

3.8 Site Activation and Verification

3.8.1 General - The principal activities identified with Tug site activation at ETR and WTR are shown in Figure III-D-12. The following activities are critical in achieving an orderly activation:

1) Facility criteria and design development;

2) Facility construction and validation;

3) GSE criteria and design development;

4) GSE construction and validation;

5) GSE installation and checkout;

6) Functional checkout of the facility and GSE using an engineering model Tug;

7) Checkout and launch of the first flight article.

The ETR site activation functional flow diagram, Figure III-D-13, shows in detail the sequence and interrelationship of these activities.

3.8.2 Facility Criteria and Design Development - NASA will be responsible for development of basic and detailed Tug requirements for each of the new or modified facilities at ETR and WTR. Preliminary and final reviews will be held to assure that all requirements had been identified before presentation to A&E contract bidders.

The detailed requirements will be presented to qualified A&E design agencies as the criteria on which to base design. The selected A&E design agency will prepare detailed drawings of the new/modified facilities. Preliminary 50%, 90%, and final design reviews will be held at NASA at ETR and WTR (as applicable). A complete drawing file will be maintained by NASA at ETR. A set of drawings peculiar to WTR will be maintained at WTR.

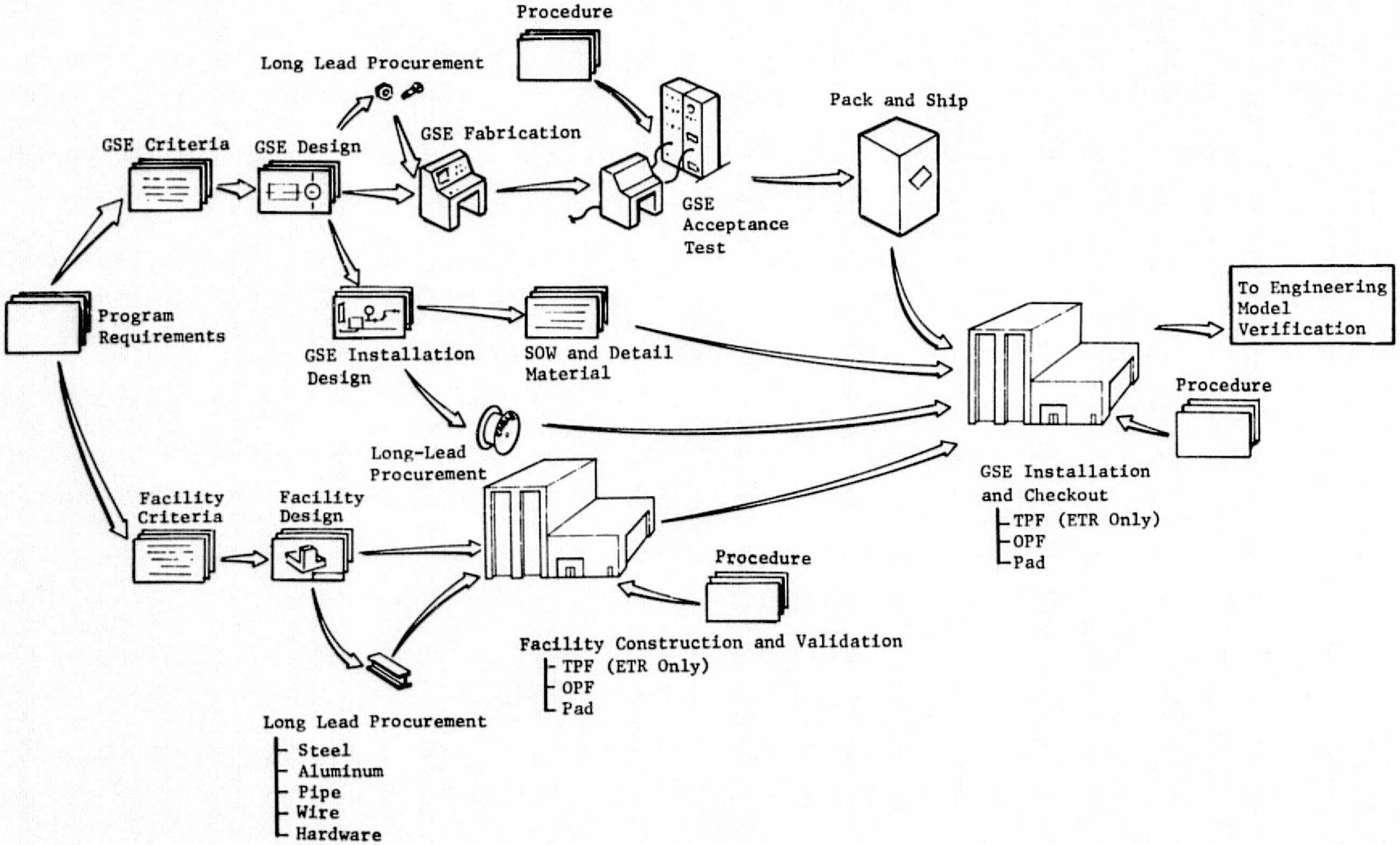
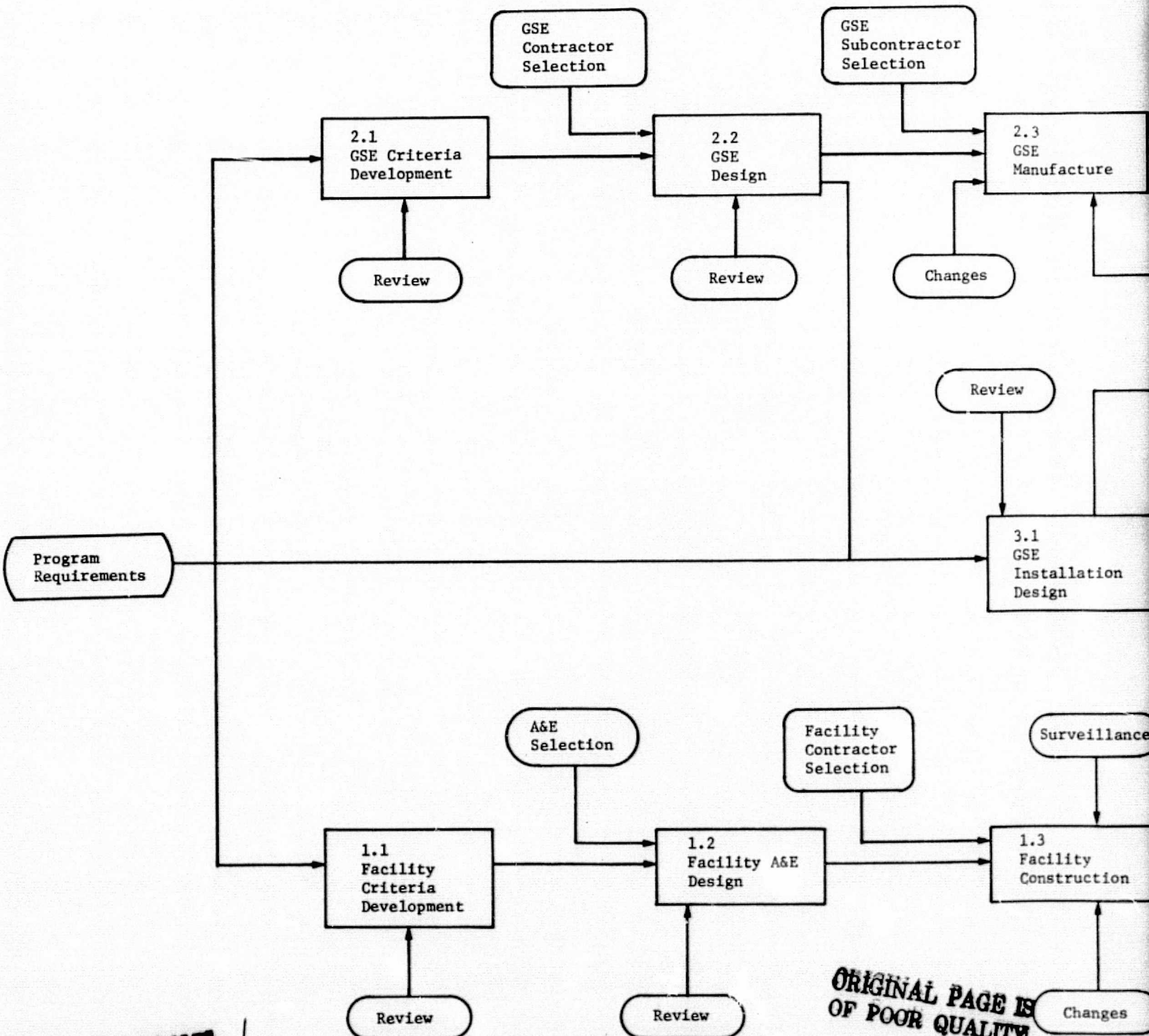


Figure III-D-12 Design/Construction Flow, Site Activation


GSE Contractor Selection
GSE Subcontractor Selection
2.1 GSE Criteria Development
2.2 GSE Design
2.3 GSE Manufacture
Review
Review
Changes
Review
Program Requirements
3.1 GSE Installation Design
A&E Selection
Facility Contractor Selection
Surveillance
1.1 Facility Criteria Development
1.2 Facility A&E Design
1.3 Facility Construction
Review
Review
Changes

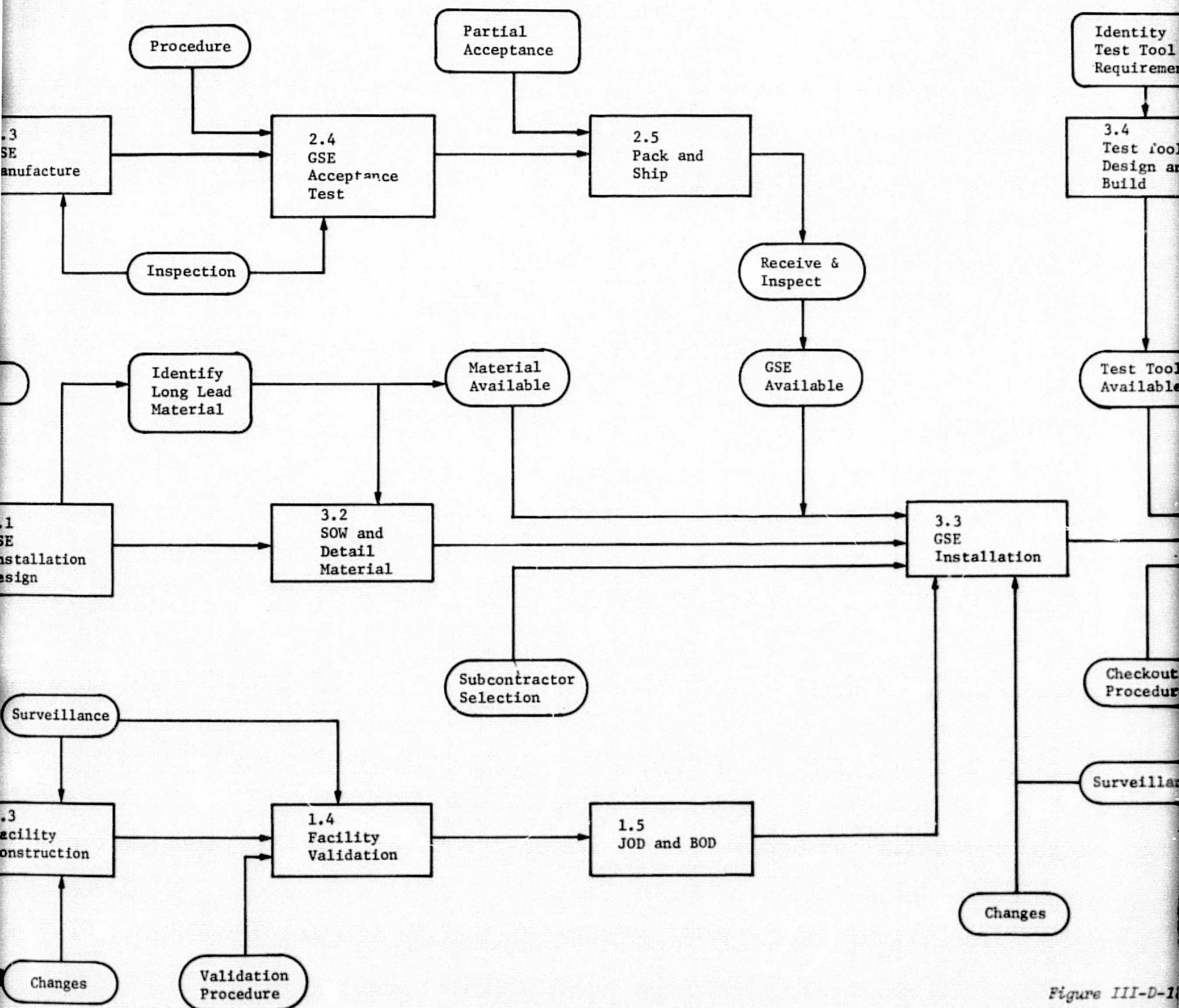


Figure III-D-1

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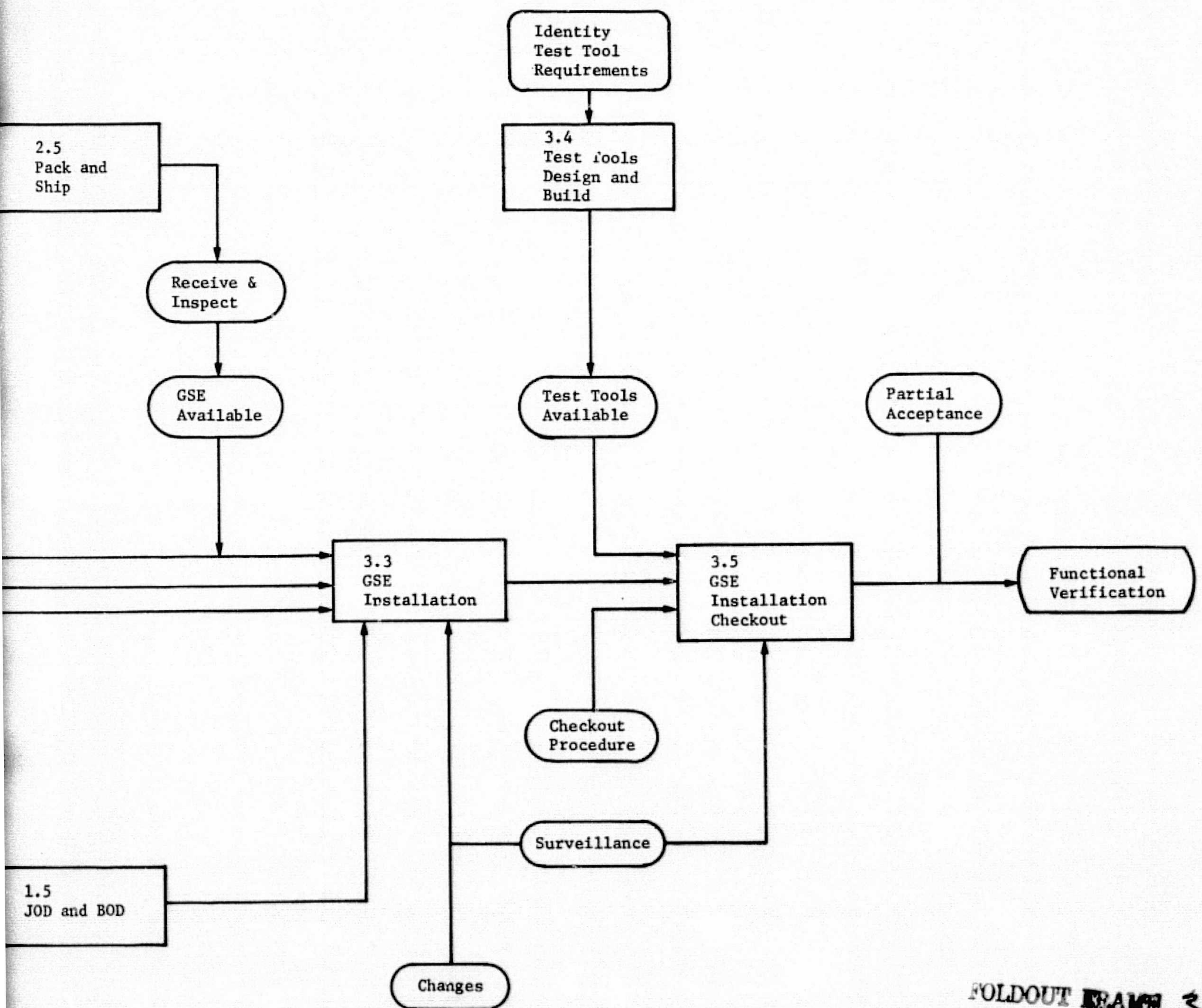

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Figure III-D-13 ETR Site Activation, Construction Functional Flow Diagram

The drawings developed in the A&E design phase will be presented to qualified construction contractors for bid. The bid cycle will be approximately 60 days.

3.8.3 Facility Construction and Validation - The selected construction contractor/contractors will perform the facility modifications under the direction of the site activation working group. A NASA facility construction surveillance team will perform physical surveillance of the work, participate in NASA/contractor progress and performance reviews, review contractor shop and detail drawings, prepare discrepancy and open item lists, review engineering changes, report to the site activation working group, and participate in beneficial occupancy date (BOD), and turnover activities.

Validation of the facility modifications will be performed by the construction contractors using validation procedures prepared by the construction contractors and approved by the site activation working group. The validation tests will be observed by facility construction surveillance team members. Final acceptance and BOD will be contingent on satisfactory completion of validation tests and closeout of open items.

3.8.4 GSE Criteria and Design Development - The NASA will be responsible for development of detailed criteria for GSE to be used at ETR and WTR. The finalized criteria will be presented to the GSE contractor.

3.8.5 GSE Design - The NASA designated GSE contractor will be responsible for the GSE design. Preliminary and final design reviews will be held as directed by NASA at ETR, WTR, and/or the GSE contractor's facility. Final approval of the design and go-ahead for construction will be given by NASA.

3.8.6 GSE Construction and Validation - The GSE contractor (or designated subcontractors) will construct the GSE at his (or the subcontractor's) manufacturing facility. Construction will be subject to inspection by NASA at all stages.

Validation of the GSE at the end-item level will be performed at the construction contractor's facility using validation procedures based on acceptance criteria developed as part of the GSE design. The validation tests will be witnessed by NASA representatives. On satisfactory completion of validation testing and resolution of open items, NASA will grant partial acceptance of that item of GSE, and the item will be packed and shipped to the using site.

3.8.7 GSE Installation and Checkout - Upon receipt at the using site, the GSE will undergo visual receiving inspection. Portable or mobile GSE will be checked for compatibility with the facility interfaces at the point of use by the GSE contractor. The GSE will be operated at the end item or subsystem level to verify operational readiness.

The GSE contractor will be responsible for installation of fixed GSE at the operational facilities. This will require preparation of installation drawings, statements of work, procurement of long lead material, letting of installation subcontracts, and surveillance/inspection of the subcontractor installation.

Checkout of the basic installation, such as, continuity testing of wiring, leak checking of pneumatic/fluid lines and holding vessels, etc, will be performed by the installation subcontractor with surveillance/inspection by the GSE contractor.

End-to-end and operational testing (at the subsystem level) will be performed by the GSE contractor using Ground System Test Procedures (GSTPs) approved by NASA, and with surveillance of the test by NASA. A partial acceptance of the GSE installation will be granted by NASA on satisfactory completion of the tests and resolution of discrepancies.

3.8.8 Functional Checkout of Facility and GSE Using an Engineering Model Tug - An engineering model of the Tug will be provided by the Tug contractor for functional checkout of the launch site systems. The engineering model will have the following characteristics identical with the flight article:

1) Forward and aft adapters;

2) Fluid, gas, and electrical interfaces;

3) Structural configuration and handling points;

4) Internal tanks, capable of being loaded with gases, APS, and main engine propellants;

5) Provisions for supporting a (typical) spacecraft;

6) Avionics.

This model can be a qualification article, such as an STA or PTV (if available), refurbished as required by the Tug contractor, or any high fidelity semifunctional Tug model. If an STA or PTV is available, existing schedules will have to be adjusted to make them available in time.

The purpose of the functional checkout is:

1) verification of operational checkout procedures;

2) verification that all facilities and GSE are operational and ready to process the flight article;

3) verification of Orbiter to Tug interfaces; and

4) crew training.

The engineering model functional checkout at ETR will proceed in the following sequence as shown in Figure III-D-14.

1) Receipt from the delivery aircraft and installation of the model on the Tug transporter;

2) Transport to TPF, purge, cleaning, and installation in checkout cell #1.

3) Complete pre-mate checkout in the checkout cell. (Using simulators for those internal functions not provided on the model, i.e., fuel cell, batteries, some avionics, etc);

4) Mate with a dummy spacecraft (one cell);

5) Tug/spacecraft interface checkout with spacecraft electrical functions provided by a simulator (one cell);

6) Load (and unload) of APS propellants and partial pressurization;

7) Insertion of the Tug/spacecraft into the transport canister;

8) Movement of the canister to the launch pad;

9) Installation in the PCR;

10) On pad checkout (in PCR);

11) Insertion into the Orbiter, and connection of Tug/spacecraft to Orbiter lines, cables, etc;

12) In-Orbiter checkout;

13) Load and unload of cryogenic propellants through the Orbiter interface;

14) Tank purging and safing;

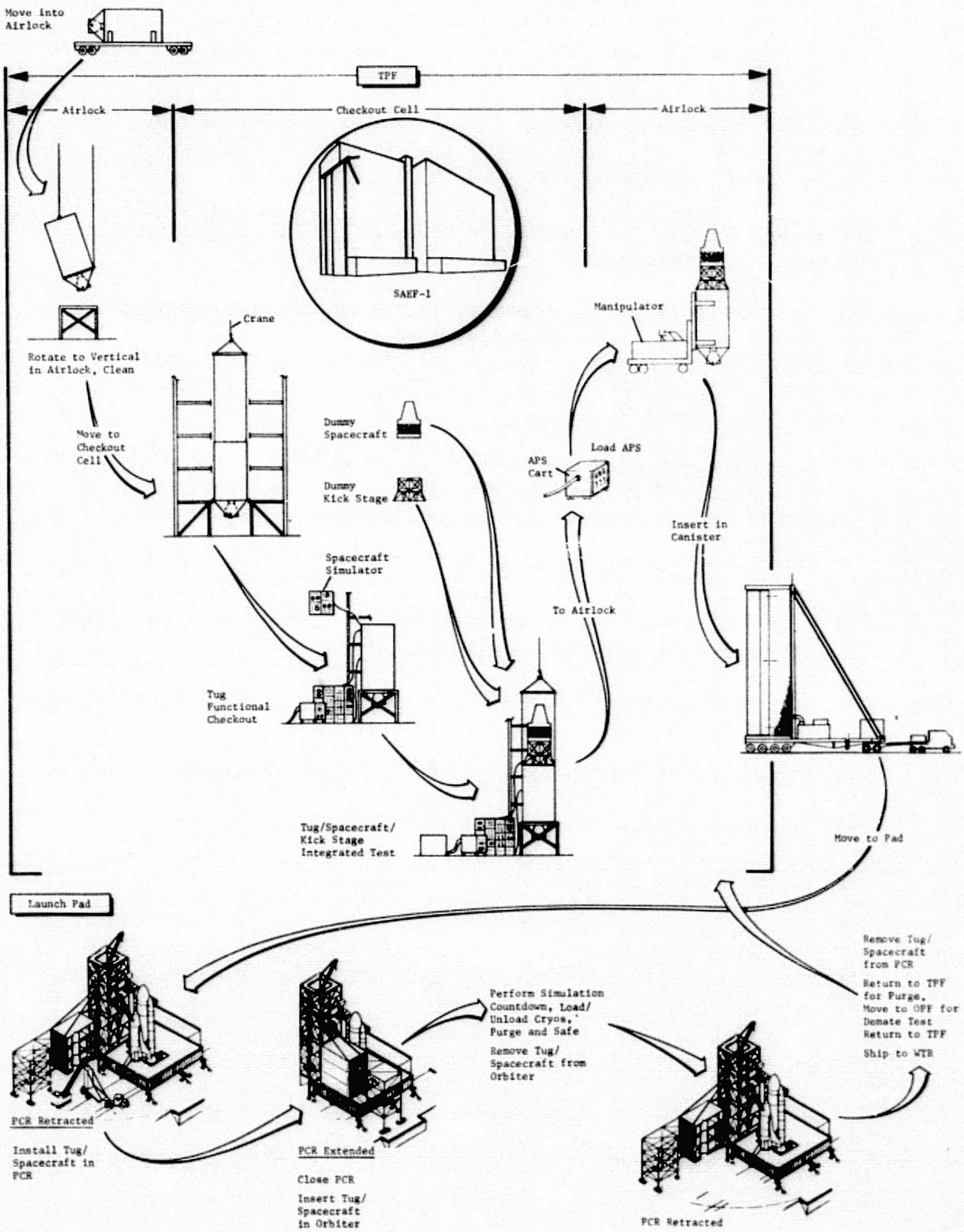

Figure III-D-14 Engineering Model Flow, Site Activation

15) Removal of the Tug/spacecraft from the Orbiter;

16) Removal from the PCR and reinsertion in the transport canister;

17) Movement from the pad to the TPF;

18) Removal of the Tug/spacecraft from the canister;

19) Tank purge and safing;

20) Movement to OPF;

21) Demate verification with Orbiter;

22) Movement to TPF;

23) Demate of Tug/spacecraft;

24) Fit check of Tug in checkout cell #2.

The engineering model Tug will be shipped to WTR to functionally verify the OPF, PPF launch pad facilities, and GSE after its use at ETR. After WTR site verification the Tug will be returned to ETR for training purposes.

3.8.9 Checkout and Launch of the First Flight Article - Processing of the first flight article will start with removal from the delivery aircraft, installation of the transport cover, and movement to the TPF, where the ground checkout will be performed in the following sequence, as shown in Figure III-D-15:

1) Tank purge;

2) Inspection and cleaning of external surfaces of the Tug in the airlock area;

3) Removal of the Tug from the transport vehicle and installation in the handling/support fixture (airlock area);

4) Installation in the checkout cell (clean bay);

5) Operational checkout of the Tug in the checkout cell, using the spacecraft simulator;

6) Receipt of spacecraft;

7) Spacecraft to Tug mate;

8) Tug/spacecraft integrated checkout;

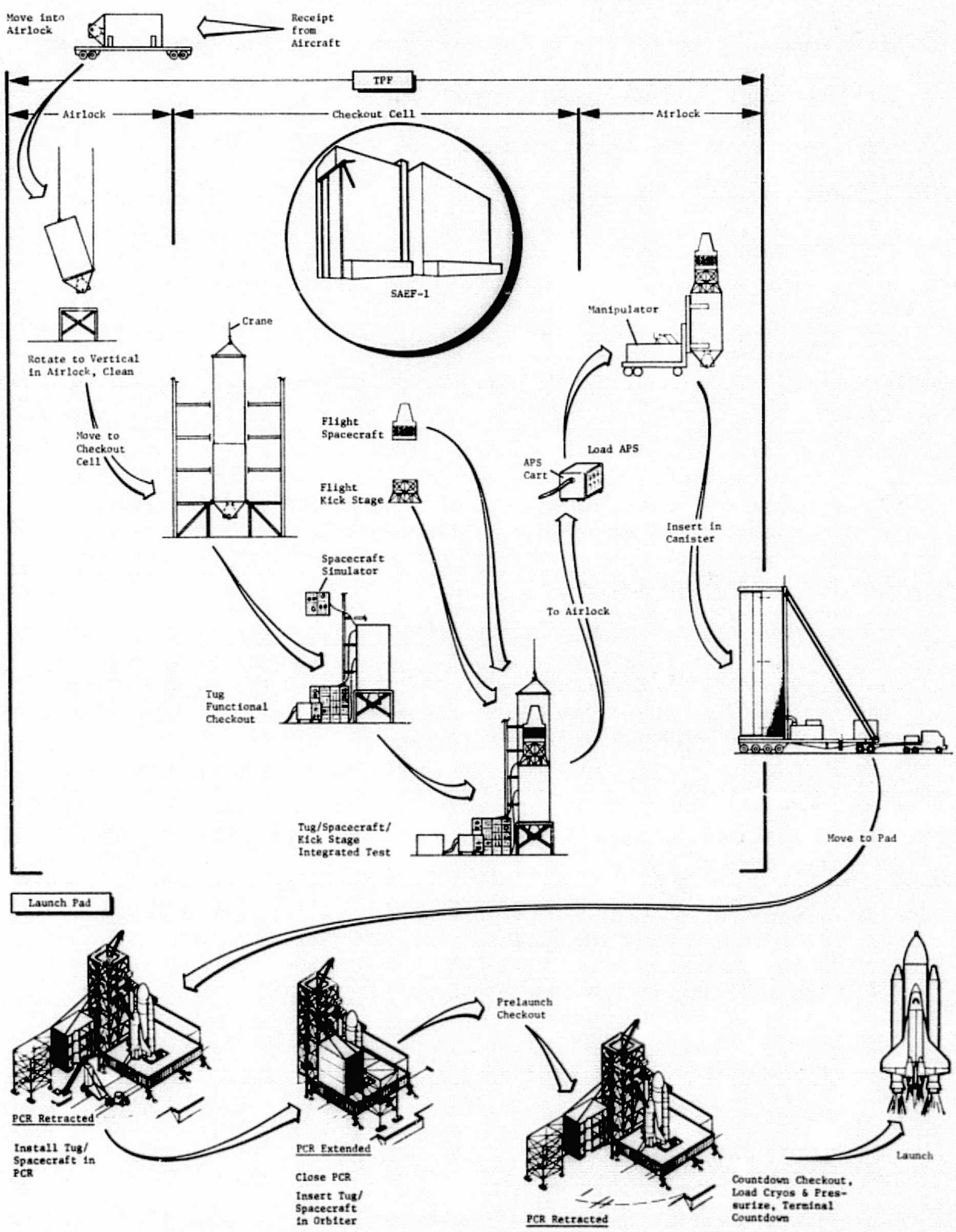

Figure III-D-15 First Flight Article Flow, Site Activation

9) Tug APS load and partial pressurization;

10) Canister positioned at airlock door and sealed;

11) Tug/spacecraft inserted in canister using the TPF manipulator. Canister doors closed;

12) Move canister to pad;

13) Open PCR, mate canister to PCR. Insert Tug/spacecraft in PCR using PCR manipulator;

14) Close PCR. Insert Tug/spacecraft in Orbiter bay. Close Orbiter bay;

15) Perform precountdown checkout;

16) Perform launch countdown, load propellants, pressurize;

17) Perform terminal countdown - launch.

3.8.10 Schedules - Planning for the Tug Site Activation Phase was based on a go-ahead date of 1 January 1980, and launch of the First Flight Article in December 1983.

Figure III-D-16 is the schedule from go-ahead to completion of the design/construction period. Figure III-D-17 shows the events during the engineering model checkout period; and Figure III-D-18 is the schedule from receipt through launch of the first flight article.

3.9 Ground Software Development

3.9.1 General - Ground software developed and/or used during the site activation phase includes:

1) mission requirements documents;

2) mission program tapes;

3) checkout criteria documents;

4) checkout program tapes and cards;

5) GSE acceptance procedures;

6) facility validation procedures;

7) GSE installation checkout procedures;

8) engineering model test procedures;

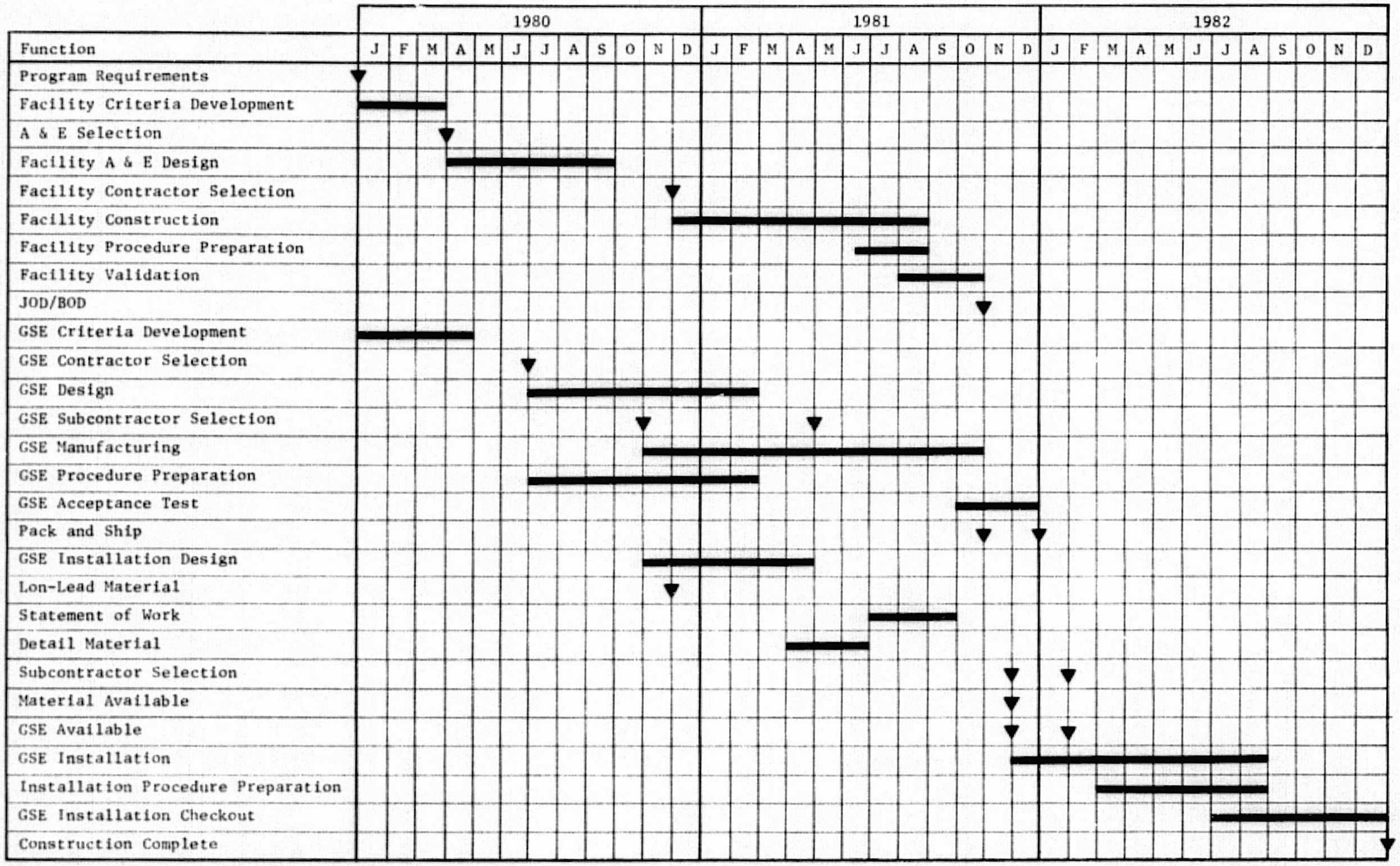

Figure III-D-16 Site Activation, Design/Construction

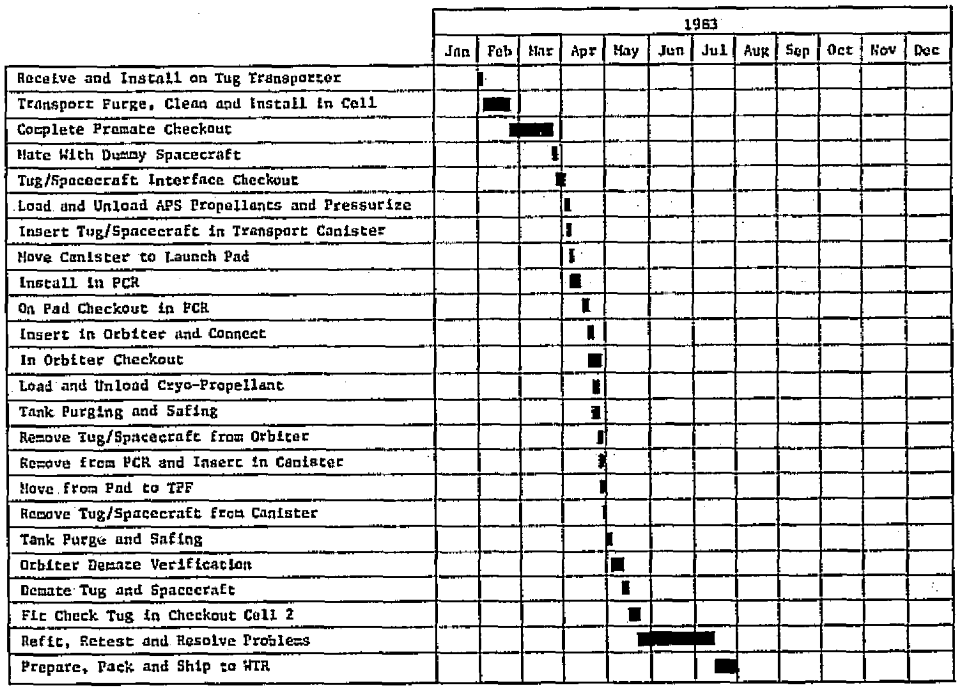

Figure III-D-17 ETR Site Activation, Engineering Model

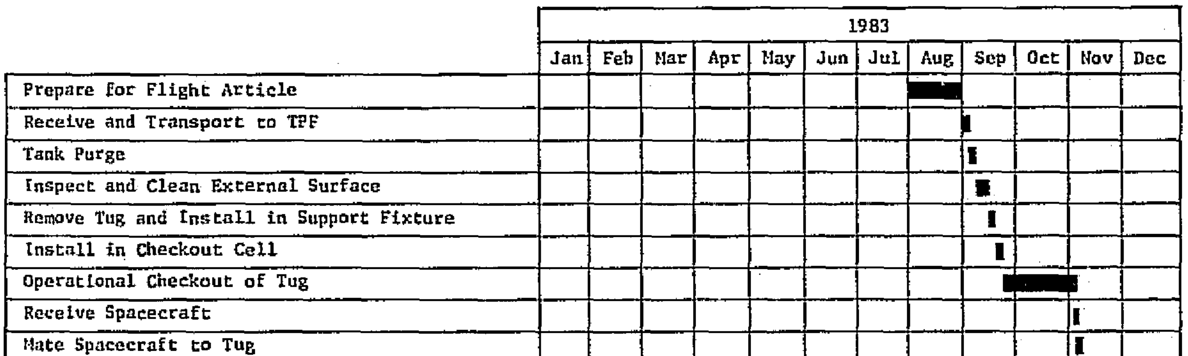

Figure III-D-18 ETR Site Activation, First Flight Article

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9) prototype operational test procedures;

10) maintenance procedures.

Mission requirements documents and mission program tapes will be developed jointly by NASA and the Tug contractor as a mission planning function. Checkout criteria documents will be developed jointly by NASA and the Tug contractor offsite, but used at ETR and WTR during the site activation phase. The development of this documentation and software is outside the scope of the site activation subplan.

It is necessary to understand the basic software development process, factor in software that should have been developed by the time the Tug is scheduled to be delivered at the launch site, and determine, from a software viewpoint, what is required of the software through the site activation process. Figure III-D-19 illustrates the LPS Software Development Process and indicates responsibilities as well as how new elements enter the process.

The LPS software contractor, IBM, will probably use a top-down programming approach that develops the system level first, the module level next, etc. Each succeeding level can contain vacant or simulated modules that could be developed later. This sets up the operating system and the support system, leaving the application programs to be developed as a package at a time when more detail is available. This method does have the advantage of defining interfaces and links well enough to test groups of modules (integrated testing) shortly after coding.

This entire process will have been repeated many times and been refined in the process. Application modules will exist that perform a wide variety of routines. Spacecraft and IUS will have entered the process many times during early Shuttle era. Tug is not expected to be a large transient on the system because it will enter the program high on the learning curve. Tug software can be developed offline and verified independently of hardware. The entire Tug software process can be developed concurrently with its own hardware development.

Validation does require element hardware to eliminate large impacts at the launch site; validation could take place at the Tug contractor's facility with a partial CCMS and telephone links to a development CDS. These preoperational engineering tests at the Tug contractor site could be used for acceptance and scientific simulation testing. Final validation/verification of the software will be done at the launch site using the Tug engineering model and the first flight article.

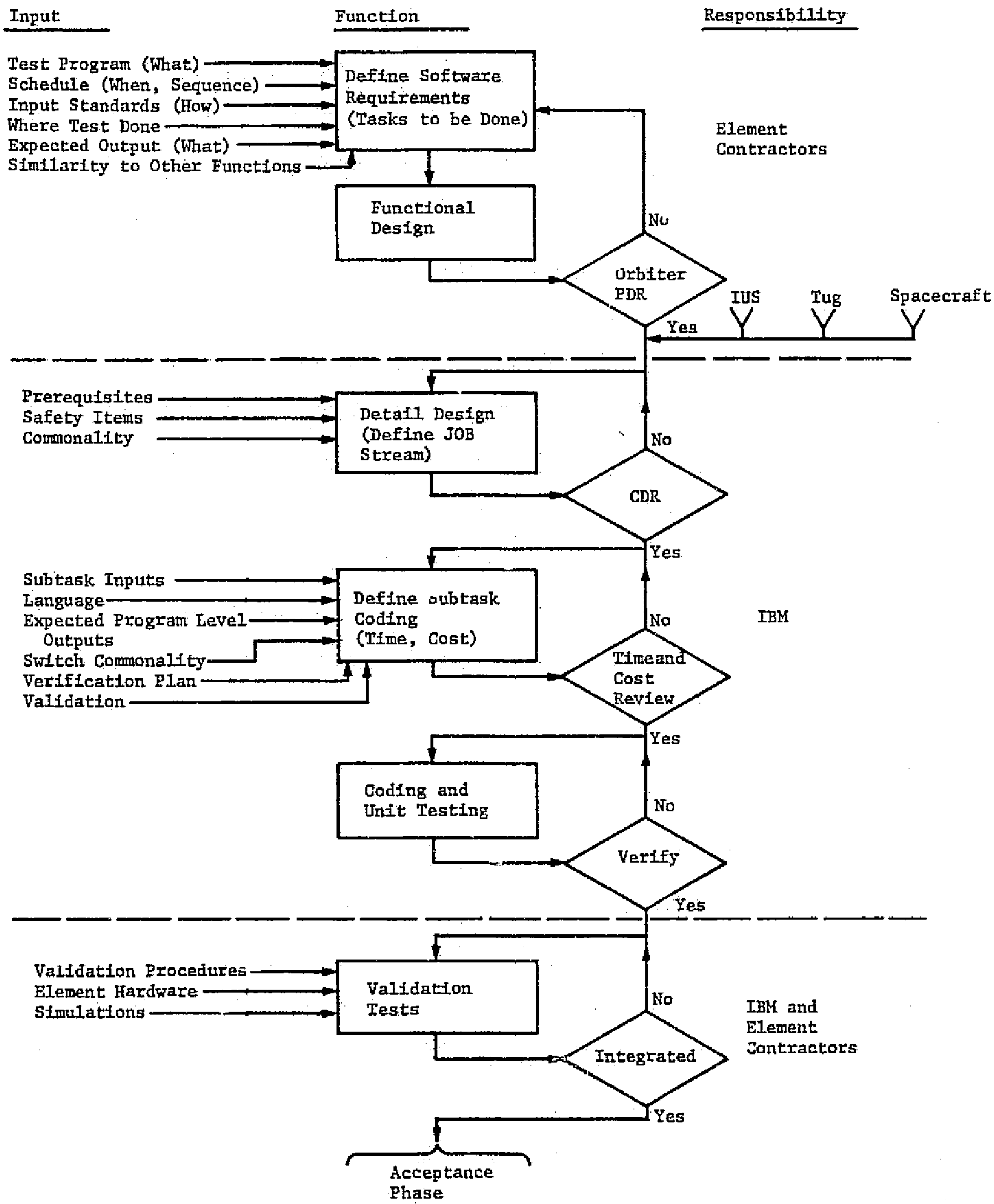


Figure III-D-19 LPS Software Development Process

The Tug checkout software development is a cooperative effort between the Tug contractor, the NASA, and IBM. The desired objective is to develop the software early, and bring it to the site integrated and validated. Software sophistication and the time allotted by the program for development lead to the conclusion that software should not be a large factor during site activation. The primary activation problems will be narrowed to hardware problems once the software has been developed.

3.9.2 GSE Acceptance Procedures - GSE acceptance procedures will be developed by the GSE contractor, or the GSE subcontractor, and approved by NASA. These procedures will be used at the GSE manufacturing site to verify design parameters of the individual end-item before acceptance by NASA, and before shipment to ETR or WTR.

Facility validation, GSE installation checkout, prototype operational, and operational procedures will be developed and used at ETR and WTR during the site activation phase. The development of these procedures is described in the following paragraphs.

3.9.3 Facility Validation Procedures - Facility validation procedures are normally developed by the facility construction/modification contractor to criteria developed during the A&E design, and approved by NASA through the site activation working group. Figure III-D-20 is a flow chart showing the stages in development of a typical facility validation procedure.

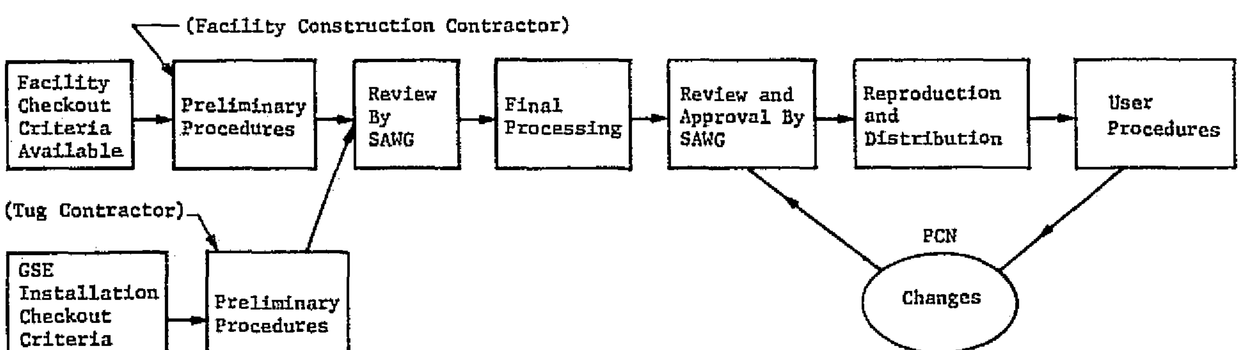


Figure III-D-20 Facility and GSE Procedure Development Flow

The procedures required to validate the new/modified facilities at ETR and WTR identified at this time are shown in Table III-D-1.

Table III-D-1 Facility Validation Procedures

Procedure No.	Facility System	Location
FVP-01-TP	Electrical Power and Grounding	TPF
FVP-02-TP	Pneumatic Piping System	TPF
FVP-03-TP	Propellant Piping System	TPF
FVP-04-TP	C/O Cell Folding Platform Functional	TPF
FVP-05-TP	Relocated Crane Functional	TPF
FVP-06-TP	Telemetry, Tracking, and Command Link (VSWR and Attenuation)	TPF
FVP-07-TP	Environmental Control System	TPF (S&M Bldg)
FVP-08-TP	LPS Links and End Station Functional	TPF
FVP-01-OP	Electrical Power and Grounding	OPF
FVP-02-OP	Crane Functional	OPF
FVP-03-OP	Pneumatic Piping System	OPF
FVP-04-OP	Propellant Disposal System	OPF
FVP-01-LP	Electrical Power and Grounding	Launch Pad
FVP-02-LP	LO_2/LH_2 Facility - GSE Interface	Launch Pad
FVP-03-LP	Pneumatic Piping System	Launch Pad
FVP-04-LP	Fixed and Folding Platforms (Modified)	Launch Pad (PCR)
FVP-05-LP	Launch Pad to LCC Hardline Link	Launch Pad

3.9.4 GSE Installation Checkout Procedures - Basic GSE installation tests such as wiring continuity, tubing, and pressure vessel leak checks, verification of weld integrity, etc, are performed by the installation contractor using standard industrial procedures.

End-to-end continuity tests of wiring, verification of piping systems, GSE end item functional tests, checkout of site modification to GSE, and verification of GSE to facility and other GSE interfaces will be performed at ETR and WTR by the GSE contractor, using GSE installation checkout procedures. These procedures will be developed by the GSE contractor and approved by NASA, as shown in Figure III-D-20.

GSE end items that are not installed, that is, portable/mobile equipment, will be functionally verified onsite using prototype/finalized operating procedures. The development of these procedures will be covered in para 3.9.5 and 3.9.6. The GSE installation checkout procedures required to verify installed GSE at ETR and WTR identified at this time are shown in Table III-D-2.

Table III-D-2 GSE Installation Checkout Procedures

Procedure No.	GSE System (or end item)	Location
GSTP-01-TP	GSE Electrical Power and Distributiuon System	TPF
GSTP-02-TP	Guidance and Navigation Test Set (A-007) Functional	TPF
GSTP-03-TP	Control and Data Acquisition Console (A-008)	TPF
GSTP-04-TP	APS Propellant Supply and Transfer Unit, Closed Loop (P-012)	TPF
GSTP-01-LC	Control and Monitor Console (A-018)	LCC
GSTP-02-LC	Propellant Load Console (A-019)	LCC
GSTP-01-LP	LH_2 Propellant Load and Pressurization Unit, Closed Loop (P-021)	Launch Pad
GSTP-02-LP	LO_2 Propellant Load and Pressurization Unit, Closed Loop (P-022)	Launch Pad

3.9.5 Engineering Model Test Procedures - The engineering model test procedures will be developed by the Tug contractor with NASA approval. Tug refurbish and checkout procedures will be of the checklist type currently used in the airline industry rather than the detailed step-by-step procedures used in the aerospace industry today. These procedures will be used at ETR and WTR during the engineering model tests and on completion of these tests, the applicable procedures will be revised and updated to support the checkout and launch of the first flight article. The procedure development flow is shown in Figure III-D-21. The actual procedures required are identified in the functional flow of section 3.1, and in the functional data sheets contained in Appendix A.

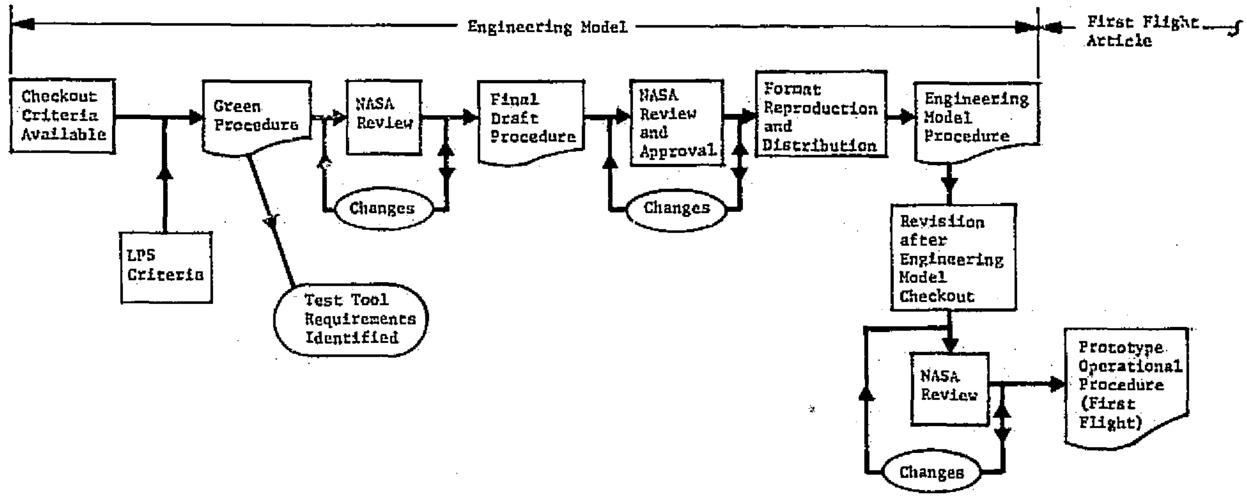


Figure III-D-21
Engineering Model and First Flight Article Procedure Development Flow

3.9.6 Prototype Operational Procedures - Prototype operational procedures will result from the procedures used in checkout of the engineering model. The first flight article Tug will be checked out, serviced, and launched using these procedures. Finalized operational procedures will develop from these procedures after update based on experience gained during processing of the first flight article, as shown in Figure III-D-21. The functions performed using the prototype operational procedures are described in the functional flow of Section 3.1 and the functional data sheets contained in Appendix A.

3.9.7 Maintenance Procedures - Procedures for periodic maintenance will be developed by the Tug contractor for ETR and WTR with NASA approval. The analysis of maintenance requirements and preparation of maintenance procedures is covered under Logistics/Maintenance, Section 3.10 of this subplan.

3.10 Logistics/Maintenance

Tug Logistics support provides necessary systems and disciplines required to ensure integrated logistics across the program. The Tug site activation phase will be used to validate and verify requirements and planning developed for the logistics support program. Special attention must be paid to the adequacy of facility and GSE design in terms of support requirements.

Management for Logistics will have responsibility for planning and implementing the total logistical support. Elements included in the overall activation logistical program are warehousing activities, tool cribs, spares selection/management, maintenance analysis, identification, developing and conducting the training program, and management of vendor documentation. Primary documentation to be prepared will be operations, maintenance, and handling manuals for the GSE, transportation and handling plans for all program equipment.

3.10.1 Facility/GSE Design - The Logistics Support Requirements Analysis will focus on GSE and facility support as well as on the Tug. Requirements identified by the analysis must be presented as timely support criteria for design. Active logistics participation in facility and GSE design reviews is required to obtain the necessary trades that will facilitate the logistics function and reduce support costs. Accessibility for GSE maintenance, maximum application of commercially available components in GSE design, adequacy of facility space and layout for planned maintenance activity, facility provisions for spares and tooling storage, etc, are typical concerns of the support analysis.

3.10.2 Maintenance Analysis - This analysis will start at the system or end item and continue to and including the lowest replaceable units. The results of this analysis will be documented on logistics requirement sheets that contain information such as: equipment location and accessibility requirements; maintenance location and prerequisites; scheduled and unscheduled maintenance tasks; equipment/supplies and technical data and procedures required to accomplish the maintenance task; spares requirements and special requirements covering: cleanliness, life limitation, packaging, storage, and transportation requirements. The logistics requirements will summarize and identify each repairable item, and the spares required to repair each item. Additional data that will be obtained and implemented during this analysis is (1) listing for spares management and inventory control, and (2) calibration requirements summary.

3.10.3 Supply - Supply activities will consist of processing all material requirements, GFP, and procured parts. Inventories will be established and maintained for operational supplies and spares support. For program economics, the contractor will use existing KSC operational supply inventories at Kennedy Space Center. A tool crib would be established to provide mechanical and electrical/electronic tool support and ensure that tools requiring calibration are cycled for calibration in accordance with established time or usage intervals.

3.10.4 Facilities and Facility Equipment - Facilities required for logistical support would be a warehouse area at or near the Tug Processing Facility to provide protective storage and processing

of all materials, GFP and contractor furnished. An area within the warehouse would serve as a bonded area for storage of critical spares and GFP. Personnel for operations of shipping, receiving, inspection, packaging, material control, spares control, warehousing activities for storage and issuance of material will be located in this area. Support services as outlined in KSC Publication KHB 8610.1A1AD would be used by contractor, providing services available are compatible with scheduled program requirements.

Facility equipment would consist of desks, chairs, file cabinets, tables, forklift for material handling, capability for cold storage, warehouse shelving and bins, power equipment for shipping container fabrication, and vehicles for material transporting.

3.10.5 Personnel Training - Personnel in test and operations that perform work related directly to Tug processing will be trained and certified in their particular specialties. All will be given familiarization courses so they will be cognizant of the overall operation. Refurbish and checkout personnel will be provided detailed instruction on Tug functional operation and be certified after satisfactorily passing course examinations and proficiency demonstrations. Periodic update and examination/certification will be required for all operating personnel to assure continuing competency. Effort required to present these courses includes the preparation of syllabus lesson plans, student study guides, certification requirements, and examinations. Certification will include systems operational function and checkout, component operational function and checkout, and individual skill certification in soldering, nondestructive testing, clean room operation component changeout and repairs.

3.10.6 Validation/Verification Activities - The engineering model flow, which will closely follow the planned Tug operational flow, will be used to the maximum extent to verify the Tug logistics program. It is suggested that a logistics demonstration program be run in parallel to the Tug engineering model flow to verify planned maintenance activity, spares availability and processing, spares transportation, procedural documentation and its change program, and operational/maintenance training.

A logistics demonstration plan will be developed specifically identifying the objectives, implementation, and scoring system to be used during demonstration activities. One phase of the program will monitor all Tug engineering model operations, starting with receipt at the airfield, and following through to insertion in the PCR. The intent during this phase will be to score the adequacy and accuracy of transportation and handling procedures, to evaluate the training program, and perform final crew training, to evaluate the logistics program in terms of time to

accomplish standard maintenance activity and to identify problems associated with the flow that affect logistics decisions and planned procedure. The second phase of the demonstration program will introduce simulated component failure into the processing flow. OFI data will be prepared in conjunction with a postflight maintenance activity plan to establish a series of maintenance actions to be performed within the maintenance timeline. Spares requirements will be generated to judge onsite spares availability and processing of the spares from central inventory to point of usage. Request will be made for production spares from the Tug manufacturer's facility, with subsequent monitoring of the transportation, receipt, handling at time required to get the spares.

Availability and adequacy of maintenance location, level, documentation, tools, and equipment will be reviewed. Selected components will be run through Levels I, II, and III maintenance on a simulated basis to judge the time required to obtain necessary support documentation, including vendor data, and to make decisions necessary for maintenance action. Access to the Tug manufacturer data base, via microfilm, terminal system, or telecon, will be demonstrated in support of simulated malfunction and repair requirements.

The problems identified during logistics demonstration will be documented in a summary report. The report will provide specific feedback to the support requirements analysis for adjustment, modification, and addition to the logistics program, in preparation for processing of the first flight article. Procedural changes will be made, individual and crew training/certification will be supplemented as required, spares and support equipment deficiencies will be corrected to provide a "ready" logistics program for the first flight article. One of the most important benefits to be gained by logistics demonstration will be assessment of the time required for maintenace activities in a real processing situation in light of overall timeline requirements. Exercising of logistics control functions, including Tug maintenance status reporting, maintenance planning, spares provisioning and recording, and reassessment of assignment of maintenance task times as a result of Tug engineering model flow, will prove the adequacy and state of preparation of fleet management operations.

3.11 Configuration Management

The configuration management processes used during the site activation phase are basically the same as those used during the operational phase. These processes are described in subplan B, IUS and Tug Fleet Utilization subplan.

3.12 *Timeline Funding*

The funding for class 100,000 clean Tug processing site activation is shown in Table III-D-3; the cost of kick stage GSE and LPS equipment at ETR and WTR are included. The IUS will require a test cell in the SAEF-1; however, a survey of transtage (IUS candidate) revealed that the required GSE was portable and could be easily relocated instead of duplicated. Therefore, the only IUS GSE costs are those of the test cell. Also included are the SAEF-1 modifications for Tug and IUS supporting processing areas, i.e., engine preparation area, avionic checkout area, storage/warehousing buildings, tool cribs, etc. The costs of launch pad/PCR and OPF modifications at ETR and WTR are included.

Table III-D-3 Site Activation Timeline Funding, $ in Millions

Function	1980	1981	1982	1983	Total
Fleet Utilization Project Management	0.26	0.50	2.07	4.78	7.61
Ground and Launch Operations, ETR	0.62	1.19	2.47	21.28	25.56
Ground and Launch Operations, WTR	0	0.50	2.52	1.96	4.98
Total	0.88	2.19	7.06	28.02	38.15

The costs shown include manpower costs. The manpower at each site is phased to reflect the program needs throughout the activation phase. The Tug Fleet Utilization Project Management Office is phased from six people in 1980 to a full staff in 1983. The ETR manpower, as shown in Figures III-D-9 and III-D-11, rises from ten in 1980 to full compliment by mid 1983. The WTR staffing reflects a smaller effort early in the program rising to its full time staff of seven in mid-1983. The number of WTR personnel increase after July 1983 to reflect the ETR crew of 34 TDY at WTR to checkout the engineering model and the first flight article scheduled for launch in December 1983.

A detailed breakout of program costs by element and time can be found in Vol III, Program Study Cost Estimates.

4.0 Alternative Approaches

Section 3.0 of this subplan has presented criteria for a single option or approach for site selection and activation. In many cases, alternatives were available in the basic approach, i.e., how to load the payload in the canister, horizontal or vertical Tug processing, APS loading and pressurization locations, etc. This section discusses these alternatives.

4.1 Canister Loading

Assuming the modified SAEF-1 as the TPF, several alternative methods of loading the canister present themselves.

1) Attach canister to clean area, seal, and open into clean area; load by means of grabber-type manipulator.

2) Attach canister to airlock door, seal, and open into airlock. Carry Tug from high bay into airlock, close high bay door, load into canister with manipulator.

3) Bring canister into airlock (or high bay), open end, and side doors, load Tug using overhead crane.

Methods 1 and 2 require the use of a manipulator. Method 1 contaminates the high bay environment temporarily. Method 3 requires a special design canister, and cleaning of the entire canister before entry into the high bay/airlock. Method 2 is the preferred method.

4.2 Horizontal vs Vertical Tug Processing

One of the basic ground rules for this study was that Tug processing would be vertical. However, the pros and cons of horizontal processing have been investigated and a summary of the results follow.

1) Horizontal processing requires less vertical height in the TPF, but requires more floor space for the same number of Tugs in process.

2) Horizontal processing requires rotation of the Tug/spacecraft/canister to the vertical position at some point in the flow to load into the PCR.

3) Horizontal processing requires rotation horizontal fixtures for processing, inspection, and mating.

4) Horizontal insertion in the canister at the TPF would allow handling by overhead crane, deleting the requirement for a Tug manipulator, but would require floor space to accommodate a canister and transport vehicle of 75 x 85 ft (22.9 x 26 m) in length (plus clearance).

5) Horizontal processing at SAEF-1 would eliminate the need to raise the airlock ceiling.

In conclusion, there is no overwhelming advantage of one method of processing over the other. However, because of desirability of vertical processing after spacecraft mating, and current concepts of canister/transporter design, the ground rule calls for vertical processing.

4.3 Tug Manipulator

A review of the Tug functional flow contained in subplan A will reveal that a considerable amount of time is involved in preparing the Tug for movement and moving it. This time is based on handling and movement within the facility, using overhead cranes. Under present planning, to move the Tug from the SAEF-1 airlock to the checkout area requires a change of cranes--airlock crane to checkout area crane. The use of a Tug ground manipulator (Fig. III-D-7) will save time in movement and movement preparation, i.e., installation of handling slings, spreader bars, spiders, tag lines, etc.

Additionally, it is inevitable that there will be unplanned maintenance and component replacement operations that will require retest by high pressure testing. Since the airlock is designed and equipped for these types of hazardous operations, ability to quickly move the Tug from the checkout area to the airlock and back will be advantageous.

The requirement for some sort of GSE manipulator exists in order to install the Tug/spacecraft assembly into the canister bay from the side. This article of GSE could be a self-powered wheeled manipulator or a framework designed to handle the Tug/spacecraft from the side while supported by an overhead crane.

4.4 APS Loading and Pressurization - Options

In order to accomplish the presently planned Tug tasks in the TPF airlock, the same requirement exists for GSE and facility as it does for the TPF checkout area, i.e.,

Function No. 2.7 - Inspection
Requires physical access to the total Tug

Function No. 2.8 - Cleaning
Requires physical access to the total Tug

Function No. 4.5 - Install Ship Loose Equipment
Requires physical access to the total Tug

Function No. 4.6, 4.7, 4.8, 4.9, 4.10 - Leak Checks
Requires access to all QDs, assumes permanently routed hoses attached to facility interfaces, permanently routed cabling attached to facility and LPS interfaces, LPS capability, etc.

In view of the above and the previous intent to have two identical checkout cells in the TPF, it appears that requirements are going to dictate almost three identical stands.

Costs versus operational requirements would appear to dictate either planning on the stand in the airlock full-up capability (3 Tugs could be in process), or transferring the planned airlock functions to the other two cells and isolate each of them so that hazardous functions in one will not affect the other (would allow 2 Tugs in process).

A totally capable stand in each checkout cell would eliminate need for moving the Tug to the airlock for APS load or high pressure testing.

5.0 Simulation Requirements

There are two types of simulators required during the site activation phase.

1) Operational Simulators - Used in normal operational checkout to simulate electrical/mechanical interfaces of flight vehicles and components when it is impractical or undesirable to test with the flight components or for normal calibration purposes. They will be used during the engineering model and first flight article checkout.

2) Activation-Only Simulators - Used only during the activation phase to verify operational readiness of the facility and GSE and to verify operational procedures.

5.1 Operational Simulators

The GSE Requirements Specification Data Sheets contained in Appendix B include descriptions of operational simulator requirements identified at this time. These are:

1) Electrical Load Banks (A-003);

2) Orbiter Cable Simulator (A-011);

3) Umbilical Simulator (A-012);

4) Star Sensor Simulator (A-013);

5) Tug/Spacecraft (Deployment) Simulator (A-014);

6) Fuel Cell Dummy Load Unit (A-015);

7) Spacecraft Docking Simulator (H-027).

Operation of all of these units will be verified during the engineering model and first flight article processing.

5.2 *Activation-Only Simulators*

1) Engineering Model Tug - The engineering model Tug will be provided by the Tug contractor. It will be used to verify Tug ground facilities, GSE, airborne interfaces, and procedures developed for checkout, servicing, and handling of the Tug at ETR and WTR.

   The characteristics of the engineering model will be identical to those of the first flight article in all essentials, including:

   forward and aft adapters;

   propellant loading, pressurization, venting, and electrical interfaces;

   internal tanks capable of being loaded with APS propellant, LH_2/LO_2 cryogenic propellants, and pressurization and purge gages;

   structural configuration and handling points;

   provisions for supporting a (typical) spacecraft or spacecraft/kick stage configuration;

   avionics;

   real or simulated response to electrical stimuli;

   simulated fuel cell.

2) Dummy Spacecraft - A dummy spacecraft will be used during the engineering model verification. This article will have the physical shape, weight, and structural interface points of a typical spacecraft (or of the first flight spacecraft). General characteristics of the dummy spacecraft would include:

   Maximum length - 30 ft (9.2 m) [or 20 ft (6.1 m) with kick stage].

   Maximum diameter - 10 ft (3 m)

   Maximum weight - 5500 lb (2495 kg)

   Aft end to mate with Tug forward adapter and/or kick stage truss.

Dummy Airborne Connectors/Quick-Disconnects - Electrical interfaces would be simulated. The dummy spacecraft or spacecraft simulation would carry no ordnance devices, propellants, or gases, nor require installation or loading of these commodities.

3) Dummy Kick Stage - This unit will simulate the physical characteristics of a solid rocket motor kick stage, as follows:

   Maximum length (including superstructure) - 10 ft (3 m)

   Maximum diameter - 10 ft (3 m)

   Aft end to mate with the Tug forward adapter

   Forward end to mate with the dummy spacecraft

   Maximum weight - 1000 lb (454 kg)

   Dummy airborne connectors/QDs

This unit will be used during engineering model verification.

PART II - FACTORY CLEAN TUG PROCESSING

1.0 Introduction

Part II provides a top level plan for the activation of a KSC facility for the processing of the Tug in a factory clean environment, and the activation approach for the factory clean processing flow presented in Addendum 6.

Part I of this subplan provided a similar plan for the activation of a KSC facility for Tug processing in a 100,000 Class clean environment and is keyed to the functional flow contained in Subplan A.

The Tug Activation Phase Subplan for factory clean tug processing describes the scope of effort required to provide operational Tug capability at ETR and WTR and IUS processing at ETR. This plan is keyed to factory clean Tug processing in joint Tug/IUS processing facility, (Option 6 presented in Subplan E.). The activation phase encompasses the period from development of facility and GSE criteria through launch of the first flight article for the Tug, and includes the following major activities:

1) Development of facility and GSE criteria;

2) Facility and GSE design;

3) Facility and GSE construction;

4) Facility and GSE validation;

5) Functional verification using a prototype Tug

6) Checkout and launch of the first flight Tug

The IUS processing facility activation described in this subplan includes the activities through Facility/GSE validation only.

These activities are described in Section 3.0. Related supporting functions, such as manpower staffing, safety, software development, logistics, and configuration management, are also covered in Section 3.0.

In the interest of clarity and to avoid repetition, Section 3.0 follows the "single option" criterion when describing facility sites, methods of operations, and flow sequences. Recognizing that in many cases alternatives are available, Section 4.0 of the subplan is devoted to describing and assessing the merits of such alternatives.

2.0 General Requirements

2.1 Ground Rules

The basic ground rules for this section of the study follow.

1) Operational Tug launch capability at ETR and WTR; however WTR would have limited maintenance and checkout capability.

2) Tug processing facility would be provided only at ETR to service both ETR and WTR. Tugs will be ferried to WTR after turnaround processing at ETR.

3) The VAB low bay to be the prime candidate for the Tug/IUS processing facility based on Option 6, Section 5.0 of Sub-plan E.

4) Tug/IUS processing to be done in a factory clean environment.

5) Spacecraft mate to be performed at the Tug/IUS processing facility in the vertical position.

6) Spacecraft to be enclosed during and after mate in a clean room with class 100,000 input air.

7) Two spacecraft enclosures to be security-safe.

8) Existing facilities and equipment to be used to the utmost.

9) Existing facilities selected to be available during the site activation phase.

10) An engineering model Tug to be available to verify new/modified facilities and GSE, if required.

11) An Orbiter vehicle would be made available at the launch complex for mating/checkout of the engineering model Tug.

12) Tug and IUS processing and transport after spacecraft mating would be performed in the vertical orientation.

2.2 Criteria and Standards

Criteria governing site selection, GSE requirements, modifications, and modes of operation are based on NASA Tug program requirements, NASA and USAF documents, standards, drawings, other current government standards, and industry standards and codes.

2.2.1 <u>NASA Program Requirements</u> -

1) MSFC68M00039-1, 15 July 1974, Baseline Space Tug System Requirements and Guidelines

2) MSFC68M00039-2, 15 July 1974, Baseline Space Tug Configuration Definition

3) MSFC68M00039-4, 15 July 1974, Baseline Space Tug Ground Operations: Verification, Analysis, and Processing

2.2.2 <u>NASA and USAF Documents and Drawings</u> -

1) NASA - Orbiter Processing Facility, Dwg 79K05423 (60%)

2) NASA - Modifications to LC-39A, Dwg 79K04402 (60%)

3) NASA - LC39 Vertical Assembly Building, Dwg 203-100 (Vol 15 and 27)

4) NASA - Support Services Handbook, KHB8610.1A/AD

5) NASA - Merritt Island Industrial Area, Facilities Space Control Document, GP680

6) NASA - Launch Complex 39, Facilities Space Control Document, (not numbered)

7) NASA - KSC Safety Program, KMI1710.1B and Att. A, KSC General Safety Plan

8) USAF - AFETRM 127-1, Range Safety Manual

2.2.3 <u>Government/Industry and Standards</u> - National Electrical Code, 1971

3.0 Site Activation Phase Study Elements

This study requires that 12 standard study elements be treated in each subplan. Not all of these are applicable to each subplan. Each element is shown under the same paragraph number in every subplan. Paragraphs 3.1 through 3.12 represent these standard study elements. The order in which subjects are treated are not necessarily chronological; therefore, they do not reflect the sequence in which the described activities would occur.

3.1 Ground Operational Flow

3.1.1 Engineering Model Flow - A Tug engineering model will be used at ETR before arrival of the first flight article. The primary objective of the engineering model will be to verify GSE interface with the Tug; however, the total intent will be to:

1) determine, document, and resolve GSE/facility/Tug interface problems, electrical, mechanical, and structural;

2) verify accuracy and completeness of Tug operational procedures;

3) verify accuracy and completeness of LPS control and monitoring software programs;

4) train personnel;

5) determine compatibility of Tug/Orbiter interfaces;

6) determine Tug/adapter/kick stage/spacecraft interface compatibility;

7) develop procedures, methods, and hardware to minimize Tug flow time for all planned and contingency functions;

8) Verify logistic approaches of transportation in a canister and airborne site shipment compatibility.

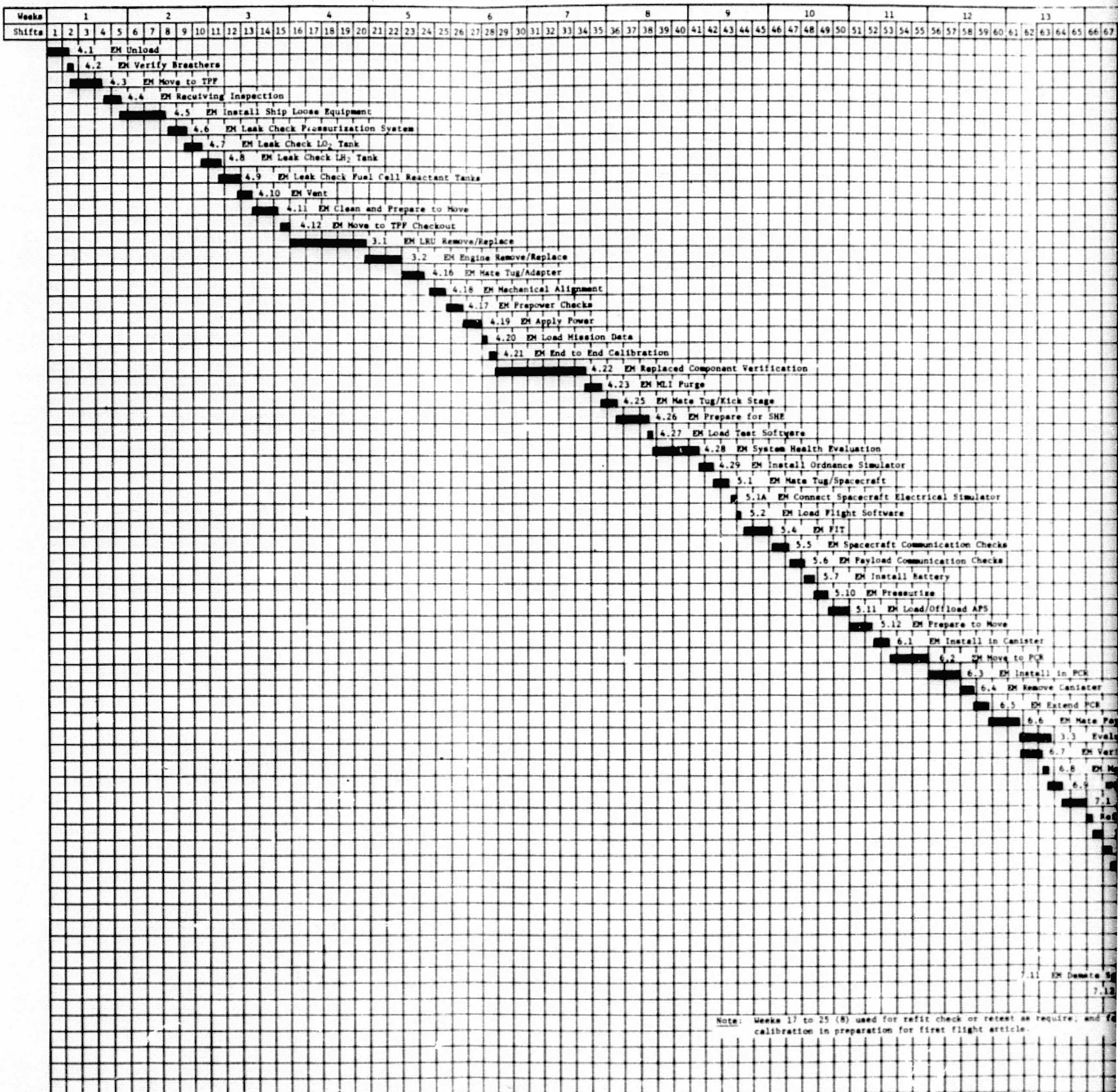
The engineering model flow depicted in Figure III-D-22 has been developed using the following assumptions and ground rules:

1) The model will be as functionally complete as a flight Tug. We recommend that the STA or PTV be evaluated for suitability in terms of capability and schedules. If either, or a combination of both, could be used for site activation, a significant cost savings could be realized.

2) The flow time for each function depicts the time required to perform that function for the first time, including minor problem correction. It does not include time for any major problem resolution that could include major procedure rewrite, major redesign, material lead time, etc.

3) The engineering model flow will follow the planned Tug operational flow as closely as possible.

4) Major interface functions such as countdown demonstration will not be performed in their entirety, but any payload/Orbiter interface functions will be performed completely.



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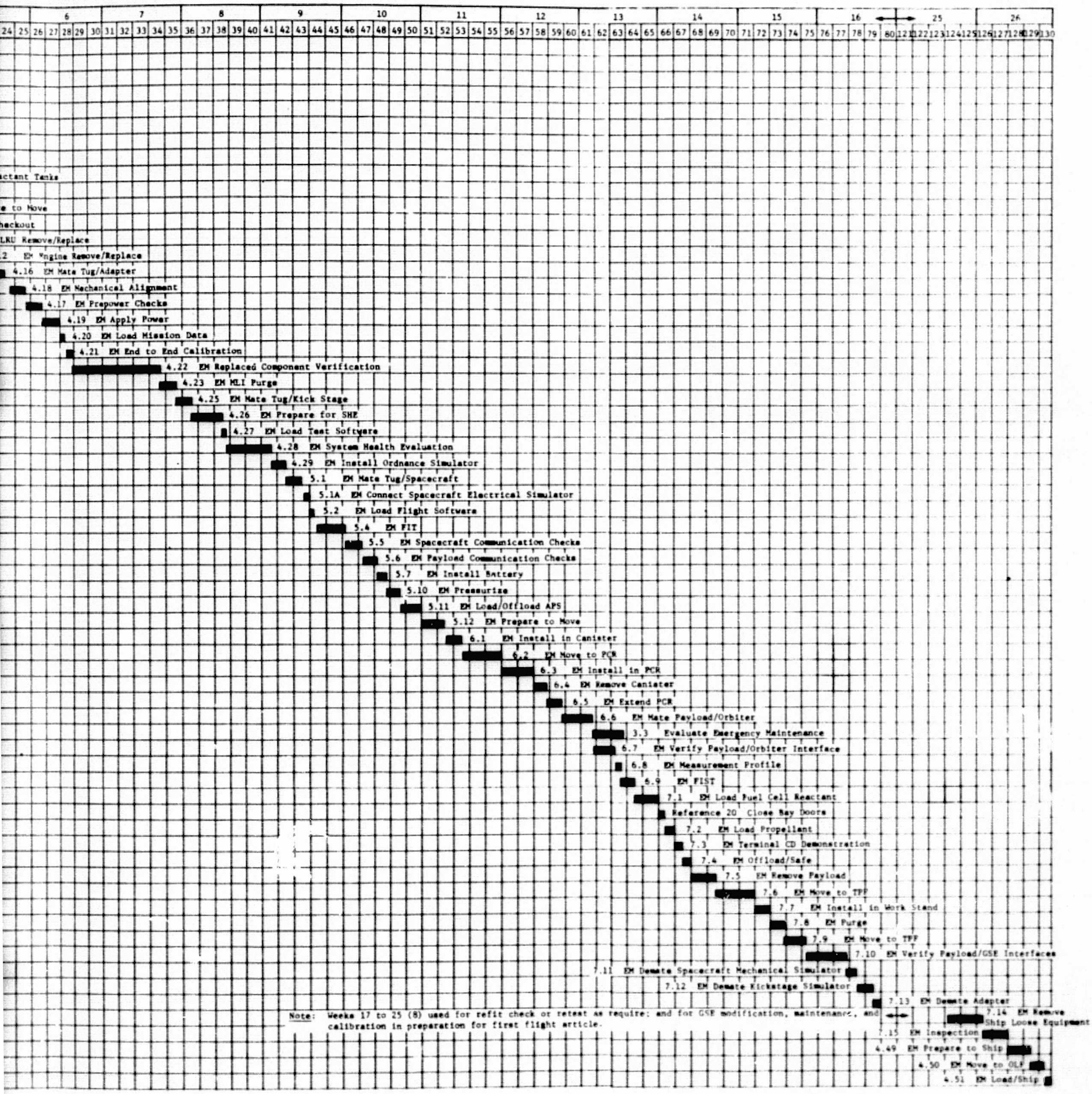

Figure III-D-22 Engineering Model Flow

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5) Tug operational procedures and LPS control and monitor software programs will be prepared by the start of the engineering model flow.

6) LPS program control of GSE will have been verified during the ground system test phase, but for safety of personnel and protection of GSE and model hardware, this GSE will be locally monitored during the engineering model flow.

7) The engineering model flow is based on a one-shift/five-day week to reduce manpower requirements and afford the capability of cross-training personnel.

8) Facility support requirements for each function have been identified before the start of the flow (personnel, type and amount of commodities, range frequencies, sampling, etc).

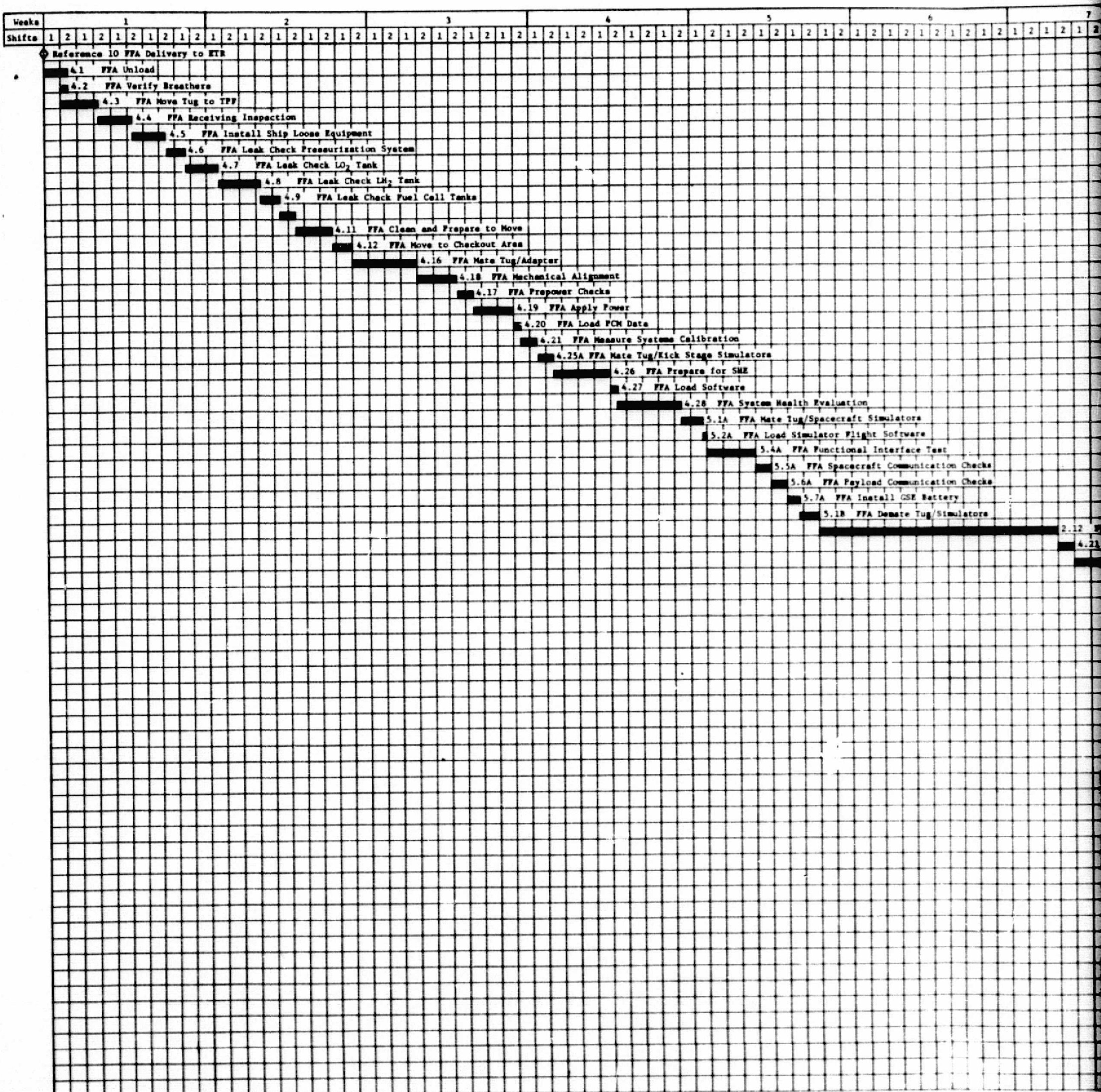
9) The Shuttle/Orbiter operation involving the PCR, orbiter to ground interfaces, etc, have been operational.

The flow of the engineering model and the first flight article will follow the same steps of the processing shown in subplan A. Function description sheets are provided in Appendix A. The operation numbers shown in Figure III-D-22, i.e., 4.1, 4.2, etc, provide cross reference to the detailed function description sheets in Appendix A. Where there is a difference between the processing of an operational Tug and the engineering model, an engineering model description sheet is provided in Appendix A.

3.1.2 First Flight Article Flow - The first flight article Tug will be used in somewhat the same manner as the engineering model. A major assumption is that the first flight article (FFA) will be delivered to ETR 90 days before launch that will provide time for problem resolution, if necessary.

The first flight article flow, Figure III-D-23, was established on the basis of 12 weeks total flow using five day work weeks of two shifts per day. As described in the function description data sheets included in Appendix A, the FFA will be processed through the planned TPF operations using kick stage and spacecraft simulators, where required, to provide total system simulation.

It is assumed that major problems concerning GSE, procedures, methods, and flight hardware interfaces will have been resolved during the flow of the engineering model. However, the objectives of the proposed FFA flow are to reverify with flight hardware, that all software, GSE, and operational methods are compatible to attain the minimum inflight article turnaround flow time.



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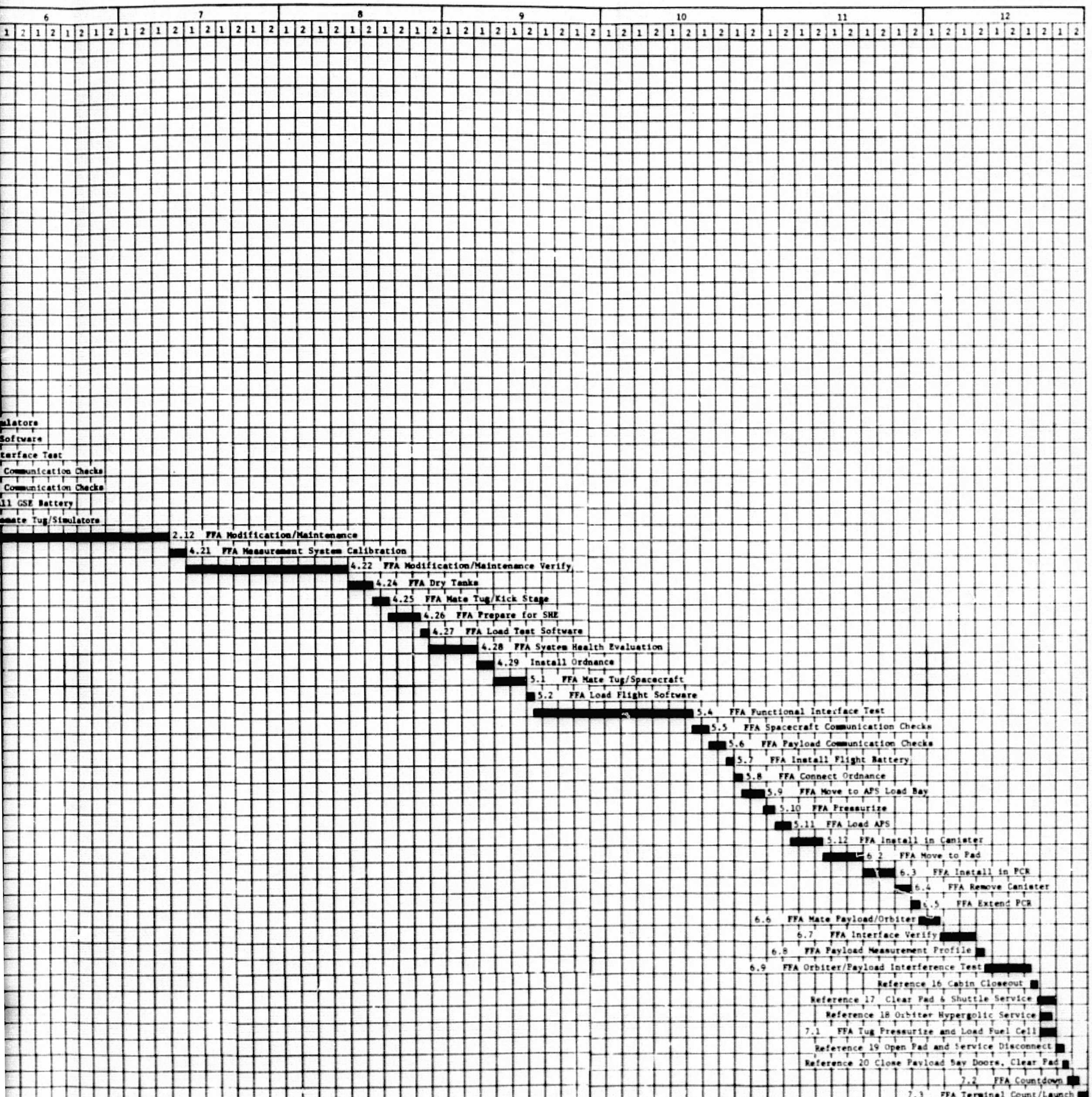

Figure III-D-23 First Flight Article Flow

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3.1.3 Critical Milestones - Assuming the first Tug launch to be December 1983 and a Tug launch site modification go-ahead in January 1980, the critical dates or milestones for KSC activities follow.

Sites

TPF available for modification	December 1980
OPF available for modification	April 1981
PCR/PAD available for modification	February 1981
TPF ready for engineering model checkout	February 1983
PCR/PAD ready for engineering model checkout	April 1983
OPF ready for engineering model checkout	June 1983

Equipment

Engineering model at KSC	February 1983
Dummy spacecraft and kick stage at KSC	February 1983
Canister/transporter available	April 1983
Orbiter available on pad for engineering model checkout	April 1983
First flight Tug onsite	September 1983
Spacecraft and kick stage ready for mate	November 1983

3.2 Facility and GSE Requirements Specification

3.2.1 Facility - New and Modified

3.2.1.1 General - The new and modified facilities identified in this study follow:

1) TPF - VAB low-bay - An existing building and support facilities at KSC, modified to provide the Tug/IUS processing facility by:

   a) Modifying two existing checkout cells for Tug processing, and two existing checkout cells for IUS processing. These four cells are identified in Figure III-D-24;

   b) modifying existing shop, lab, office, and storage areas to support Tug and IUS processing.

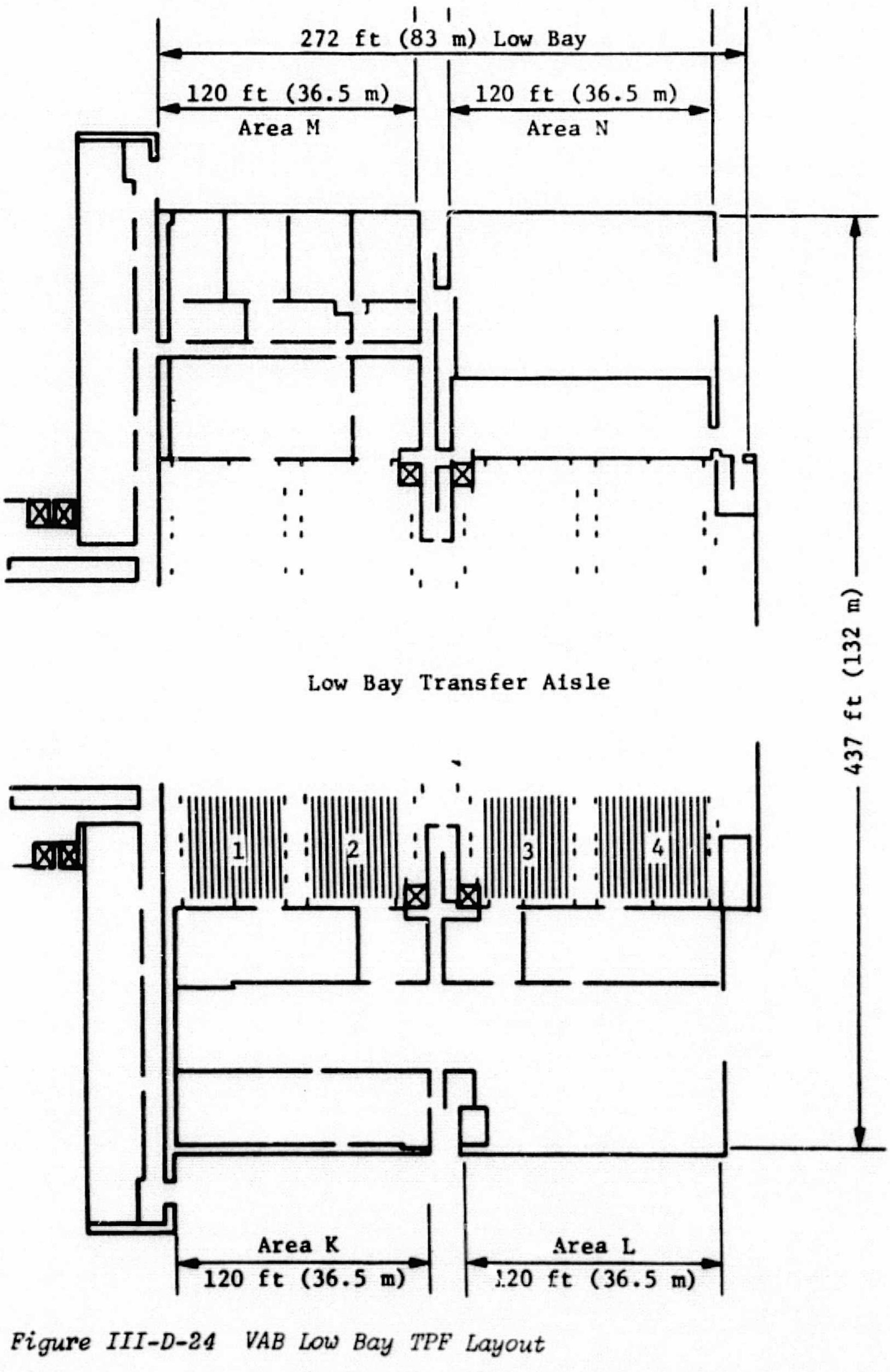


Figure III-D-24 VAB Low Bay TPF Layout

More detailed description of the VAB low-bay modifications is given in Section 3.2.1.2 and alternative low bay layouts are discussed in Section 4.1.

2) Launch Complex 39A - The assumption is made that the PCR has been constructed and in use for the IUS program, and that an IUS-to-Orbiter insertion manipulator is in existence. The principal modifications to LC39A to accommodate the full Tug/spacecraft/kick stage combination then become:

   a) modification/adjustment of PCR platforms to accommodate Tug/spacecraft diameters and work stations,

   b) modification/adjustment of the PCR manipulator for the Tug diameter and hard point locations,

   c) modification of existing LH_2 and LO_2 piping to interface with new GSE Tug LH_2/LO_2 propellant loading units,

   d) addition/modification of LPS interfaces for Tug requirements,

   e) provision of electrical interfaces at the LCC for GSE Tug monitoring and propellant loading consoles.

3) Kick Stage Processing Facility - An existing facility (to be determined) for processing the solid rocket motor kick stage. Facilities under consideration include:

   a) Explosive Safe Area-60-A (CCAFS),

   b) TIIIC SRM Facility (CCAFS).

   Peculiar handling equipment would be provided as GSE. Existing electrical/pneumatic sources would accommodate kick stage requirements using GSE adapters.

4) Orbiter Processing Facility - The existing facility being developed for Shuttle postflight processing should include these Tug pecular requirements, including:

   a) an 8-ton (7260 kg) overhead crane capability;

   b) 150x60 ft (46x18.3 m) floor area;

   c) storage and maintenance area;

   d) eye washes and showers;

e) added/relocated electrical outlets and pneumatic connections;

f) office and crew space.

Tank purge, propellant disposal and Tug/spacecraft handling equipment would be furnished as GSE.

5) Spacecraft Processing Facilities - Individual spacecraft requirements will determine any facility modification requirements to the existing facilities at CKAFS and KSC where NASA and DOD spacecraft are processed at present. These include buildings AO, AM, AE, SAB (at CKAFS) and the O&C Building, SAEF #1 and SAEF #2 (MILA Industrial Area). Additional facilities may be required depending upon spacecraft launch rate and launch preparation/checkout time.

6) WTR Facilities - With the Tug processing facility at ETR only, the new/modified WTR facilities required to support Tug operations would include:

a) OPF - Modified to provide crane support, Tug-peculiar commodities, office, crew, shop, and storage space;

b) PCR/Pad SLC-6 - Modified to provide propellant and pneumatic interfaces for the GSE LH_2 and LO_2 loading units and LPS interfaces; platform modifications/adjustments for Tug diameter and working stations; modification/adjustment of the PCR manipulator to accommodate Tug hard points; addition of electrical interfaces in the Control Center for Tug monitor and loading consoles;

c) Payload Processing Facility (PPF) - A facility modified to accept Tug and Tug GSE for Tug/spacecraft integrated checkout.

3.2.1.2 TPF-VAB Low Bay Modifications - Modifications to the VAB low bay and adjacent areas required to provide Tug and IUS processing capability follow:

1) Platforms and movable stands in cells 1 and 2 modified to accommodate the 14.7 ft (4.5 m) diameter Tug.

2) Platforms and movable stands in cells 3 and 4 modified to accommodate the 10 ft (3 m) diameter IUS.

3) Cells to be enclosed and air conditioned. Spacecraft levels to have class 100,000 clean inlet air available.

4) Cell doors to be sealable to canister entry.

5) Provide "slick" surface floors, walls, and ceilings where particulate cannot settle and later recirculate due to work activities and air circulation.

6) Additional security provisions to be made for one Tug cell and one IUS cell at the spacecraft level.

7) Air conditioning will require two primary A/C units, two backup A/C units, ducting, and control equipment. Ducts and electrical wiring to be made secure for cells 2 and 3.

8) Upgrading of the existing monorail cranes to a minimum 7-ton (6350-kg) capacity.

9) Propellant disposal piping and vent/burn stacks to be added from the cells to the VAB roof. Floor drains, wash-down hoses, and eye washes are to be provided. (Propellants requiring disposal facilities include for the Tug, H_2, O_2, N_2H_4, and for the IUS, N_2H_4, UDMH, and N_2O_4.)

10) Provision of a Tug cell checkout Control Room (for control consoles, LPS terminal, etc). (To be a modified existing room.)

11) Allocation of existing rooms for labs, shops, offices, and personnel locker rooms.

12) Modification of existing areas to provide environmentally controlled bonded storage areas.

13) Blast barriers to be provided between adjacent cells.

Figure III-D-25 shows a proposed layout of the VAB low bay cells 1 and 2 and the adjoining support areas to accommodate the Tug processing facility requirements. Figure III-D-26 shows cells 3 and 4, which would be modified to accommodate IUS checkout facility requirements. Figure III-D-27 depicts a typical external view of the checkout cells showing the door arrangement into the transfer aisle. Figure III-D-28 presents a typical internal view of the checkout cells showing the clean area locations.

3.2.1.3 *Security Provisions* - Additional security provisions will be added to one Tug and one IUS cell at the spacecraft levels for use during checkout of DOD spacecraft. Included in these provisions will be the following:

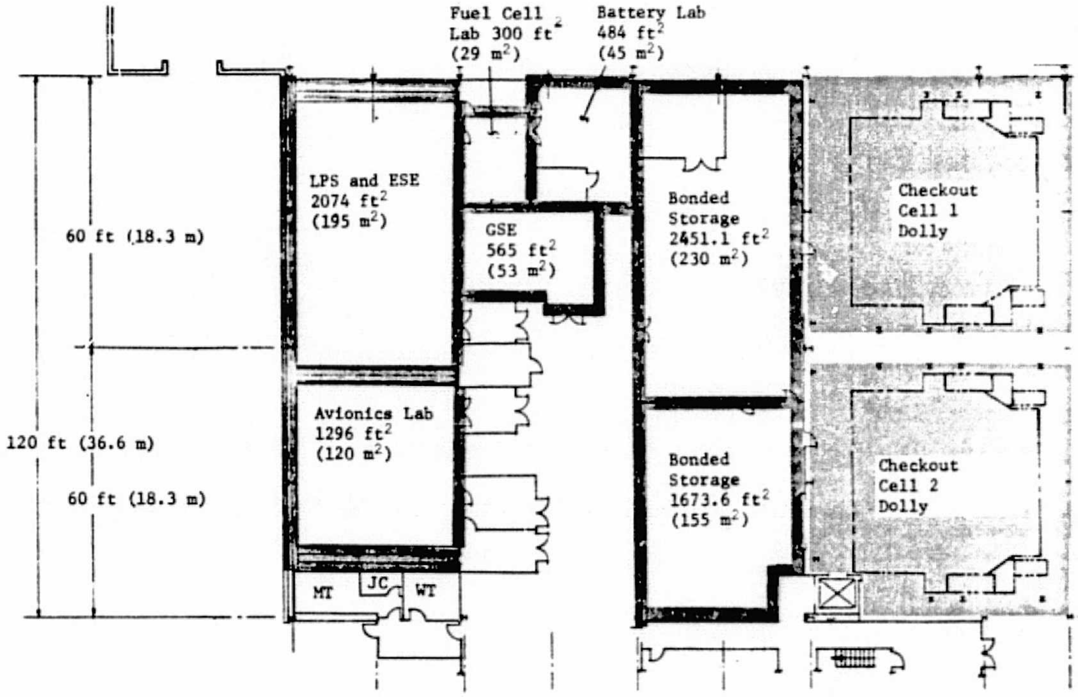


Figure III-D-25 VAB Low Bay Tug Processing Area

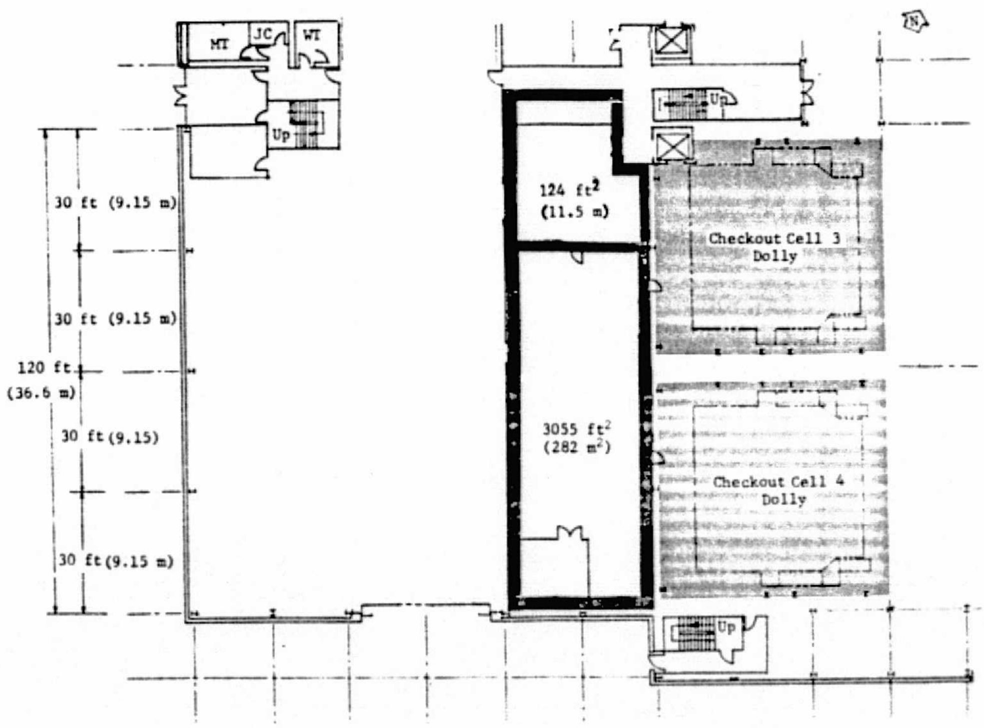


Figure III-D-26 VAB Low Bay IUS Processing Area

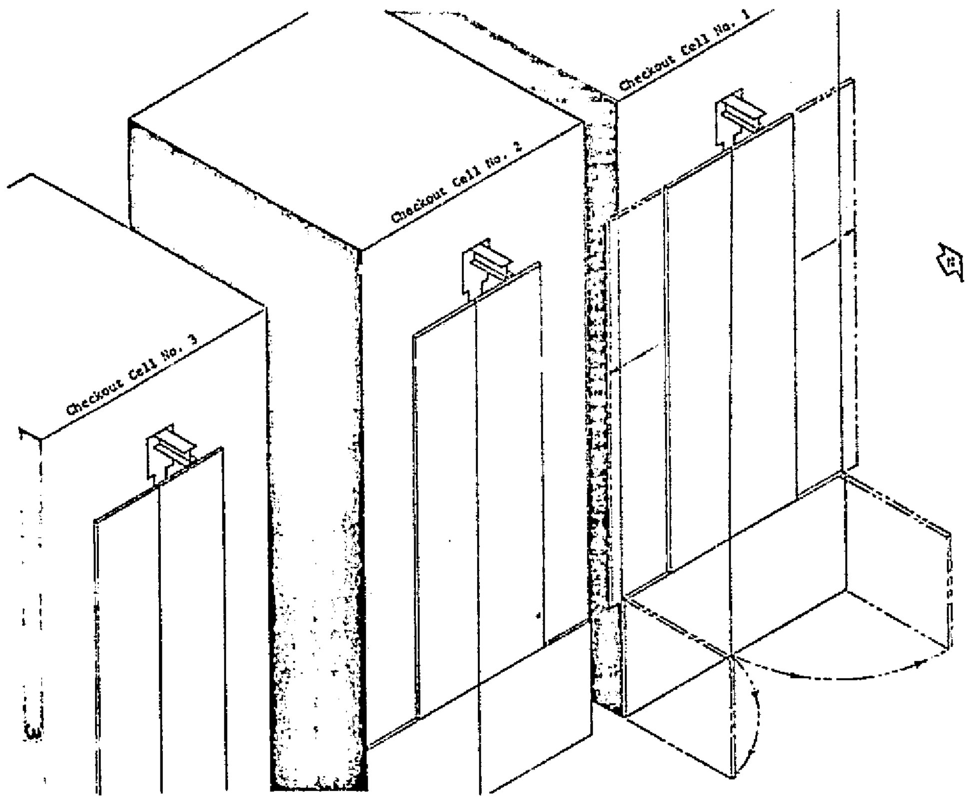


Figure III-D-27 VAB Low Bay Area K

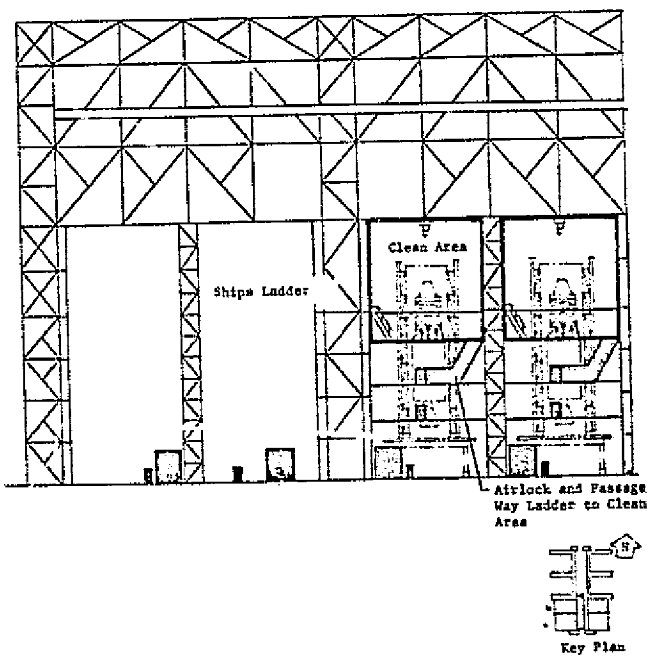


Figure III-D-28 VAB Low Bay Cell Clean Area

1) Entry into the spacecraft clean room by authorized personnel will be via an airlock at one level only. The airlock will be constructed so that there is no direct line-of-sight into the secure area from outside, and inner and outer doors will be interlocked. A security guard will be posted at the entrance to the airlock. All personnel will be logged in and out.

2) Equipment entry will be provided at one level via airlock. This entry will normally be closed except when moving equipment and will not be used for personnel entry.

3) Emergency exit doors will be provided at all work levels. These doors will be made so they cannot be opened from the outside.

4) Movement of personnel between levels will be by ladder or stairway within the secure area.

5) A display panel will be provided at the guard station to indicate when a door is open or closed.

6) Blue, revolving beacon lights will be provided to indicate when a DOD spacecraft is in the secure area.

7) Wide-band rejection filters will be installed in all power and lighting circuits entering the secure area.

8) All necessary openings into the area will be baffled to prevent viewing and/or provided with steel bar grills to prevent personnel entry (including inlet and outlet air-conditioning ducts).

9) There will be no direct view into the secure area from the lower cell levels.

10) The opening at the bottom of the spacecraft will be sealed with a boot that is provided with an R-F seal.

3.2.1.4 *Tug Facility Requirements Specification Data Sheets* - The new/modified facilities requirements are described in detail in the Tug Facility Requirements Specification Data Sheets contained in Appendix D.

3.2.1.5 *IUS Facility Requirements* - The IUS checkout cell facilities in the VAB low bay have been described previously. IUS facility requirements at the OPF, launch pad and other sites are outside the scope of this subplan.

3.2.2 GSE - The new/modified operational GSE to be used during Tug site activation will include:

1) avionics checkout and monitoring equipment;

2) handling, access, and transportation equipment;

3) propulsion, pneumatic, and mechnical checkout and servicing equipment;

4) structural integrity inspection equipment.

The Tug GSE required is identified and described in detail in the Tug GSE specification data sheets contained in Appendix B.

3.3 Transportation Requirements and Support

3.3.1 Tug Canister/Transporter - The canister/transporter concept developed in previous studies could be used on the Tug program. Figure III-D-29 shows one proposed concept for this equipment.

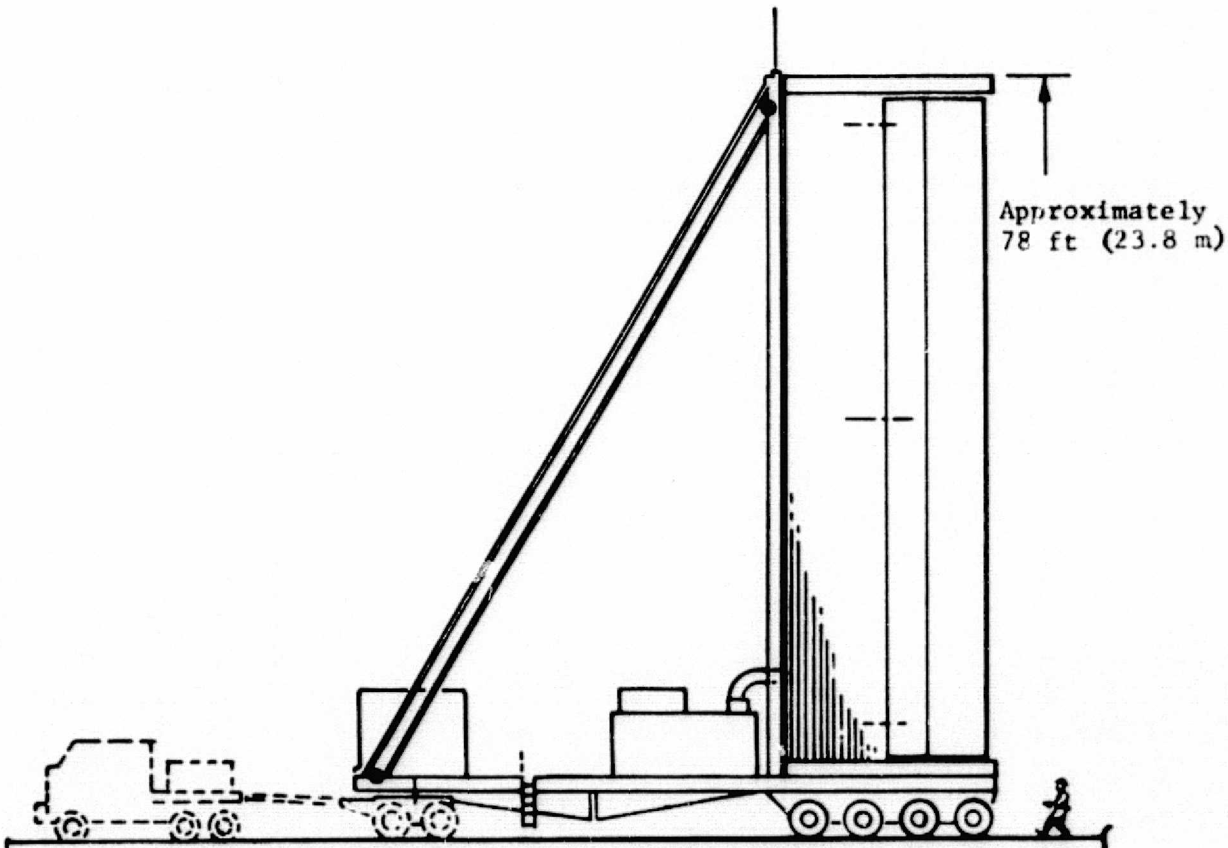


Figure III-D-29 Canister/Transporter

Should the equipment final design evolve a universal canister/transporter, then adaptation for Tug would involve only adjustment of the internal mounting hard points to accommodate the Tug diameter and hard point locations. If the universal concept proves impractical, the basic requirements for Tug would be the following:

1) Capability of housing a 15 ft (4.6 m) diameter by 60 ft (18.3 m) length payload that could consist of Tug/kick stage/spacecraft or other configurations in a vertical position;

2) Environmental control of the canister during transport;

3) Swing-open door entry and through-the-top access;

4) Capability of sealing the entrance against the TPF cell door opening and at the PCR;

5) Self-leveling of the transporter during the ascent of the launch pad ramp at ETR.

3.3.2 Tug Transportation - The Tug peculiar transportation requirements are described in detail in the GSE Requirement Specification Data Sheets in Appendix B. These requirements can be summarized as follows:

1) A Tug transtainer for transport to and from the aircraft, with provision for maintaining a clean environment when shipping a checked-out Tug from ETR to WTR;

2) A kick stage transtainer;

3) A spacecraft transport vehicle (provided as a spacecraft-peculiar requirement by the spacecraft agency).

Transportation of the Tug and major ship-separate subassemblies from the supplier to ETR will be by air, with the Tug horizontal. There are no requirements for keeping the Tug vertical during transport checkout.

3.4 Operational Data Requirements

Not applicable to Site Activation Phase subplan.

3.5 Manpower Staffing

The Tug site activation phase can be divided into three phases:

1) Planning, design, and construction;

2) Facility/GSE Verification with a Tug engineering model;

3) Processing, checkout, and launch of the first flight article.

The manpower staffing during the activation period is based on the requirements through these phases, resulting in gradual buildup from a skeleton force to a full operational crew.

For purposes of organizational responsibility, the activation phase essentially consists of a facility/GSE construction period and a vehicle utilization period. The construction period covers the activities from facility/GSE criteria development through construction, and validation of the facility/GSE installations. The proposed organization manpower estimates, and overall facility modification schedules for factory clean Tug processing facility activation are the same as for clean Tug processing modifications. The depth of detail that this study addresses does not permit a detailed evaluation of each modification and new construction and the resource requirements to complete it.

The transition to the vehicle utilization period will occur on completion of the construction/installation validation effort. It is anticipated that the transition will be smooth because personnel used in the first period will now have support functions in the second period.

3.6 Safety Requirements and Support

The safety requirements and support approach for factory clean Tug processing are the same as those for Class 100,000 clean Tug processing. These requirements may be found in para 3.6 of Part I of this subplan.

3.7 Fleet Utilizaton and IUS/Tug-to-Payload Integration Requirements

Not applicable to Space Tug Site Activation Phase subplan.

3.8 Site Activation and Verification

3.8.1 General - The principal activities identified with Tug activation at ETR and WTR are shown in Figure III-D-30. The following activities are critical in achieving orderly activation:

1) Facility criteria and design development;

2) Facility construction and validation;

3) GSE criteria and design development;

4) GSE construction and validation;

5) GSE installation and checkout;

6) Functional checkout of the facility and GSE using and engineering model space tug;

7) Checkout and launch of the first flight article.

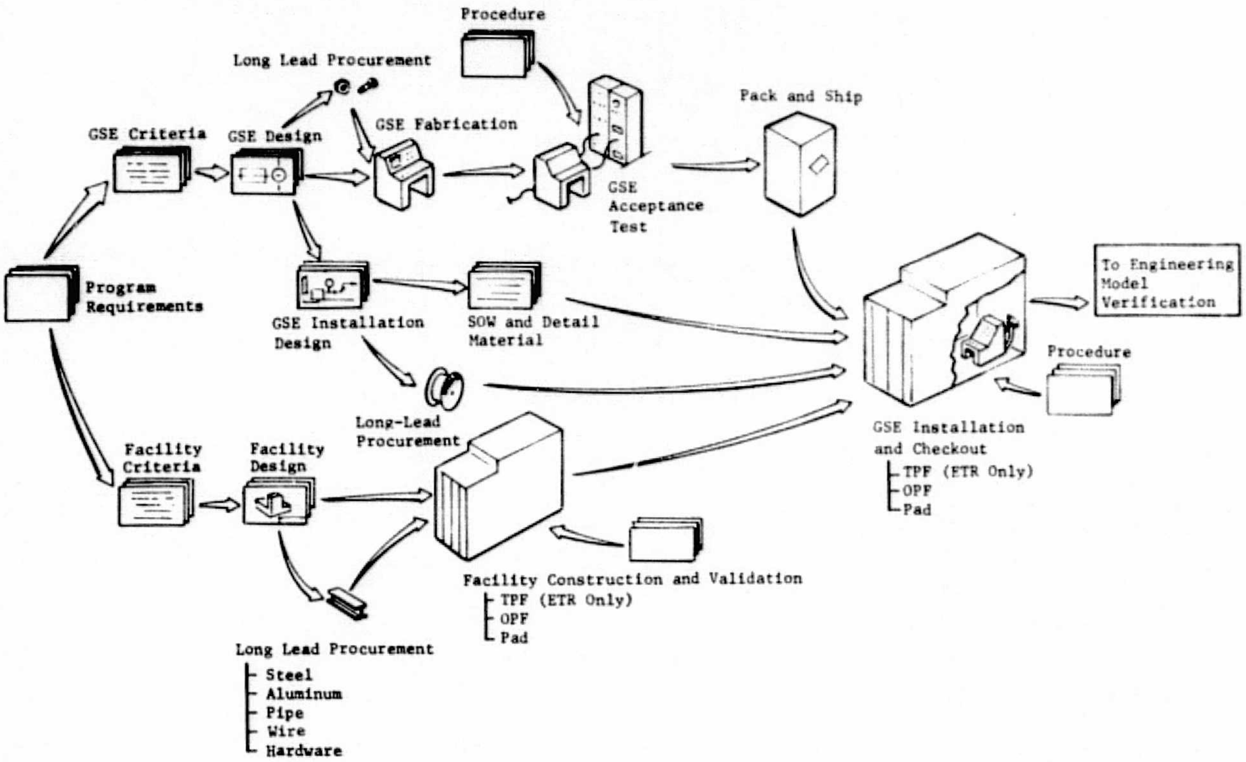
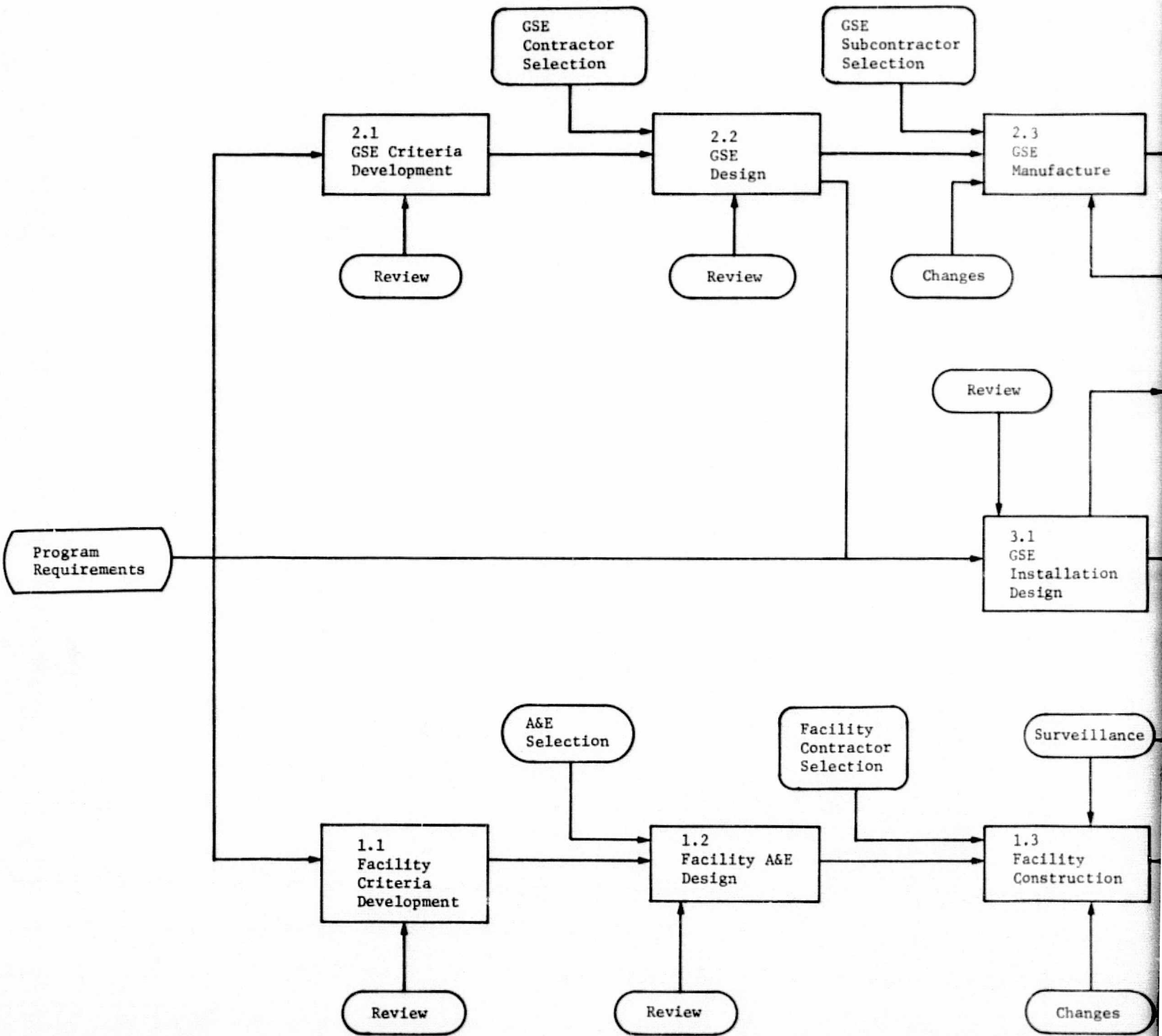


Figure III-D-30 Design/Construction Flow, Site Activation

The functional flow diagram shown in Figure III-D-31 shows in detail the sequence and interrelationship of these activities.

3.8.2 Facility Criteria and Design Development - NASA will be responsible for development of basic and detailed Tug requirements for each of the new or modified facilities at ETR and WTR. Preliminary and final reviews will be held to assure that all requirements had been identified before presentation to A&E contract bidders.


GSE Contractor Selection
GSE Subcontractor Selection
2.1 GSE Criteria Development
2.2 GSE Design
2.3 GSE Manufacture
Review
Review
Changes
Review
Program Requirements
3.1 GSE Installation Design
A&E Selection
Facility Contractor Selection
Surveillance
1.1 Facility Criteria Development
1.2 Facility A&E Design
1.3 Facility Construction
Review
Review
Changes

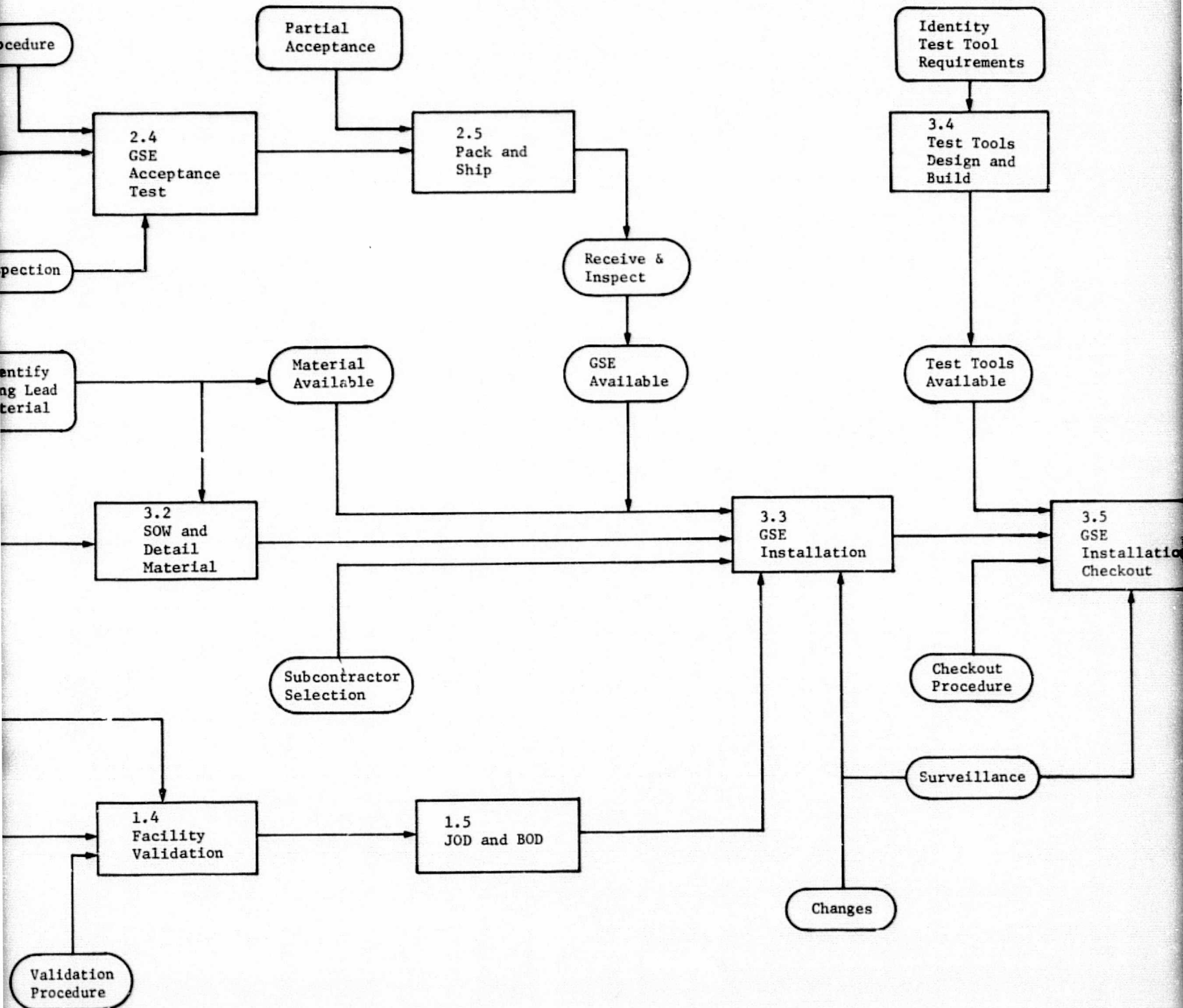


Figure III-D-31 ETR Site Activation, Con

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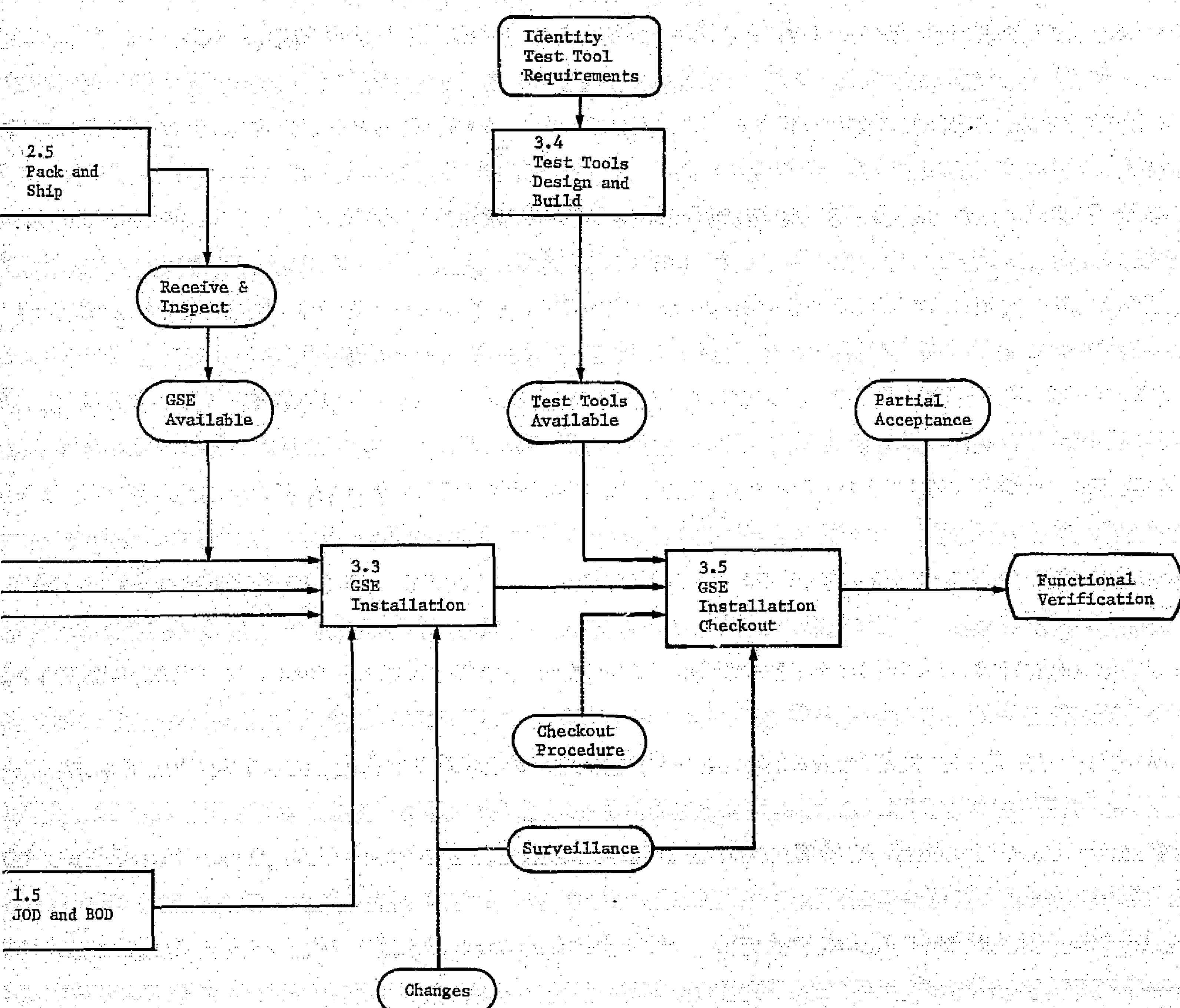

Figure III-D-31 ETR Site Activation, Construction Functional Flow Diagram

The detailed requirements will be presented to qualified A&E design agencies as the criteria upon which to base their design. The selected A&E design agency will prepare detailed drawings of the new/modified facilities. Preliminary, 50%, 90% and final design reviews will be held by NASA at ETR and WTR (as applicable). A complete drawing file will be maintained by NASA at ETR. A set of drawings peculiar to WTR will be maintained at WTR.

The drawings developed in the A&E design phase will be presented to qualified construction contractors for bid. The bid cycle will be approximately 60 days.

3.8.3 Facility Construction and Validation - The selected construction contractor/contractors will perform the facility modifications under the direction of the site activation working group. A NASA facility construction surveillance team will perform physical surveillance of the work, participate in NASA/contractor progress and performance reviews, review contractor shop and detail drawings, prepare discrepancy and open item lists, review engineering changes, report to the site activation working group, and participate in Beneficial Occupancy date (BOD) and turnover activities.

Validation of the facility modifications will be performed by the constuction contractors using validation procedures prepared by the construction contractors and approved by the site activation working group. The validation tests will be observed by facility construction surveillance team members. Final acceptance and BOD will be contingent on satisfactory completion of validation tests and close-out of open items.

3.8.4 GSE Criteria and Design Development - NASA will be responsible for development of detailed criteria for GSE to be used at ETR and WTR. The finalized criteria will be presented to the GSE contractor.

3.8.5 GSE Design - The NASA designated GSE contractor will be responsible for the GSE design. Preliminary and final design reviews will be held as directed by NASA at ETR, WTR, and/or the GSE contractor's facility. Final approval of the design and go-ahead for construction will be given by NASA.

3.8.6 GSE Construction and Validation - The GSE contractor (or designated subcontractors) will construct the GSE at his (or the subcontractors) manufacturing facility. Construction will be subject to inspection by NASA at all stages.

Validation of the GSE at the end-item level will be performed at the construction contractor's facility using validation procedures based on acceptance criteria developed as part of the GSE design. The validation tests will be witnessed by NASA representatives. Upon satisfactory completion of validation testing and resolution of open items, NASA will grant partial acceptance of that item of GSE, and the item will be packed and shipped to the using site.

3.8.7 GSE Installation and Checkout - Upon receipt at the using site, the GSE will undergo visual receiving inspection. Portable or mobile GSE will be checked for compatibility with the facility interfaces at the point of use by the GSE contractor. The GSE will be operated at the end-item or subsystem level to verify operational readiness.

The GSE contractor will be responsible for installation of fixed GSE at the operational facilities. This will require preparation of installation drawings, statements of work, procurement of lead material, letting of installation subcontracts, and surveillance/inspection of the subcontractor installation.

Checkout of the basic installation, such as, continuity testing of wiring, leak checking of pneumatic/fluid lines and holding vessels, etc, will be performed by the installation subcontractor with surveillance/inspection by the GSE contractor.

End-to-end and operational testing (at the subsystem level) will be performed by the GSE contractor using Ground System Test Procedures (GSTPs) approved by NASA, and with surveillance of the test by NASA. A partial acceptance of the GSE installation will be granted by NASA on satisfactory completion of the tests and resolution of discrepancies.

3.8.8 Functional Checkout of Facility and GSE Using an Engineering Model Tug - An engineering model of the Tug will be provided by the Tug contractor for functional checkout of the launch site systems. The engineering model will have the following characteristics identical with the flight article:

1) Forward and aft adapters;

2) Fluid, gas, and electrical interfaces;

3) Structural configuration and handling points;

4) Internal tanks, capable of being loaded with gases, APS, and main engine propellants;

5) Provisions for supporting a (typical) spacecraft;

6) Avionics.

This model can be a qualification article, either the STA or PTV refurbished as required by the Tug contractor or any high fidelity semifunctional model. If the STA or PTV is selected, existing schedules will have to be adjusted to make them available in time.

The purpose of the functional checkout is fourfold:

1) Verification of operational checkout procedures;

2) Verification that all facilities and GSE are operational and ready to process the flight article;

3) Verification of Orbiter to Tug interfaces;

4) Crew training.

The engineering model functional checkout at ETR will proceed in the following sequence as shown in Figure III-D-32:

1) Receipt from the delivery aircraft and installation of the model on the Tug transporter;

2) Transport to TPF, purge, cleaning, and installation in checkout cell #1.

3) Complete pre-mate checkout in the checkout cell. (Using simulators for those internal functions not provided on the model, i.e., fuel cell, batteries, some avionics, etc);

4) Mate with a dummy spacecraft (one cell);

5) Tug/spacecraft interface checkout with spacecraft electrical functions provided by a simulator (one cell);

6) Load (and unload) of APS propellants and partial pressurization;

7) Insertion of the Tug/spacecraft into the transport canister;

8) Movement of the canister to the launch pad;

9) Installation in the PCR;

10) On pad checkout (in PCR);

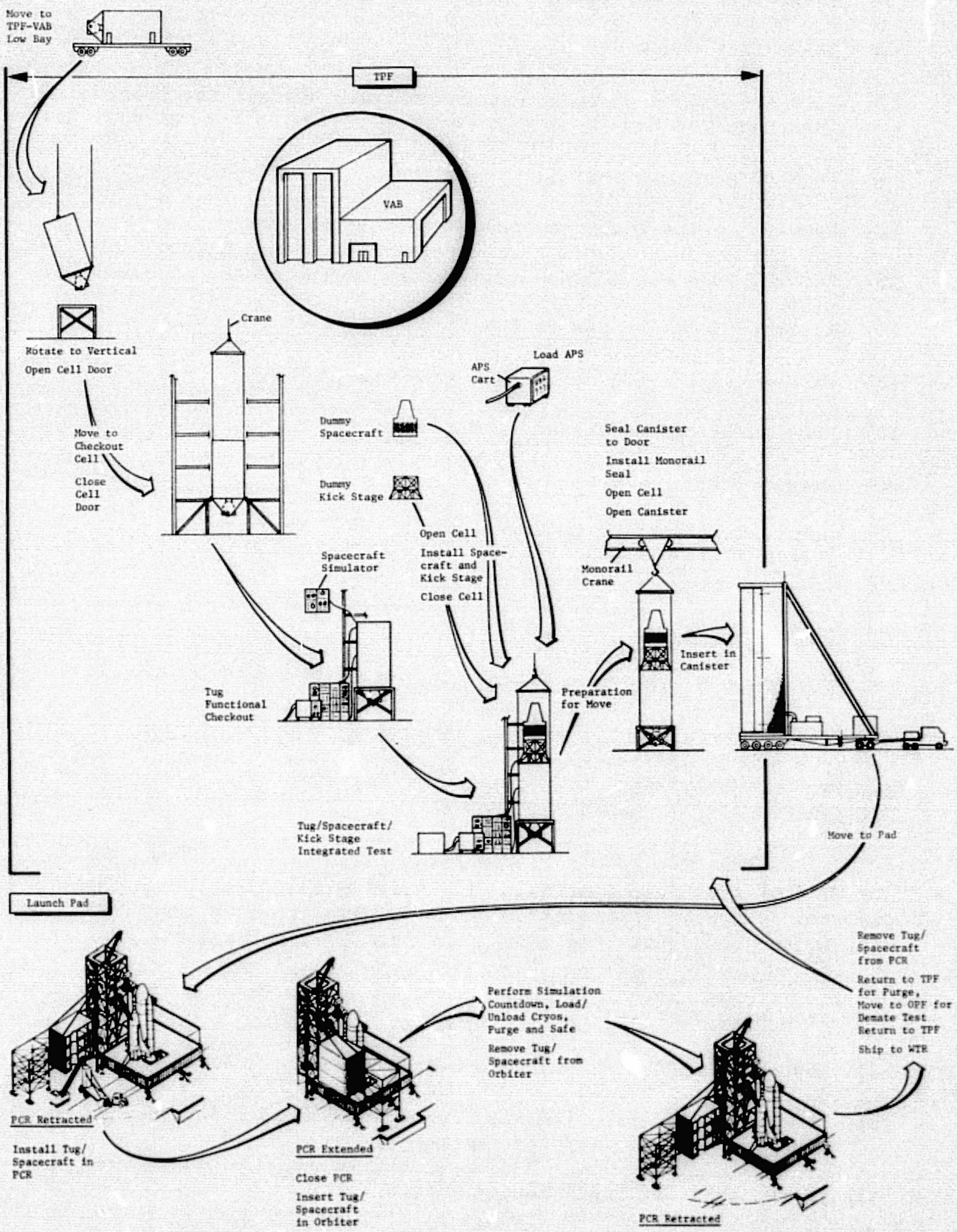

Figure III-D-32 Engineering Model Flow, Site Activation

11) Insertion into the Orbiter, and connection of Tug/spacecraft to Orbiter lines, cables, etc;

12) In-Orbiter checkout;

13) Load and unload of cryogenic propellants through the Orbiter interfaces;

14) Tank purging and safing;

15) Removal of the Tug/spacecraft from the Orbiter;

16) Removal from the PCR and reinsertion in the transport canister;

17) Movement from the pad to the TPF;

18) Removal of the Tug/spacecraft from the canister;

19) Tank purge and safing;

20) Move to OPF;

21) Demate Verification and Orbiter;

22) Move to TPF;

23) Demate the Tug/spacecraft;

24) Fit check of Tug in checkout cell 2.

The engineering model Tug will be shipped to WTR to functionally verify the OPF, PPF, launch pad facilities, and GSE after its use at ETR. After WTR site activation, the Tug will be returned to ETR for training purposes.

3.8.9 Checkout and Launch of the First Flight Article - Processing of the first flight article will start with removal from the delivery aircraft, installation of the transport cover, and movement to the TPF, where the ground checkout will be performed in the following sequence, as shown in Figure III-D-33:

1) Tank purge;

2) Inspection and cleaning of external surfaces of the Tug;

3) Removal of the Tug from the transport vehicle and installation in the handling/support fixture;

4) Installation in the checkout cell;

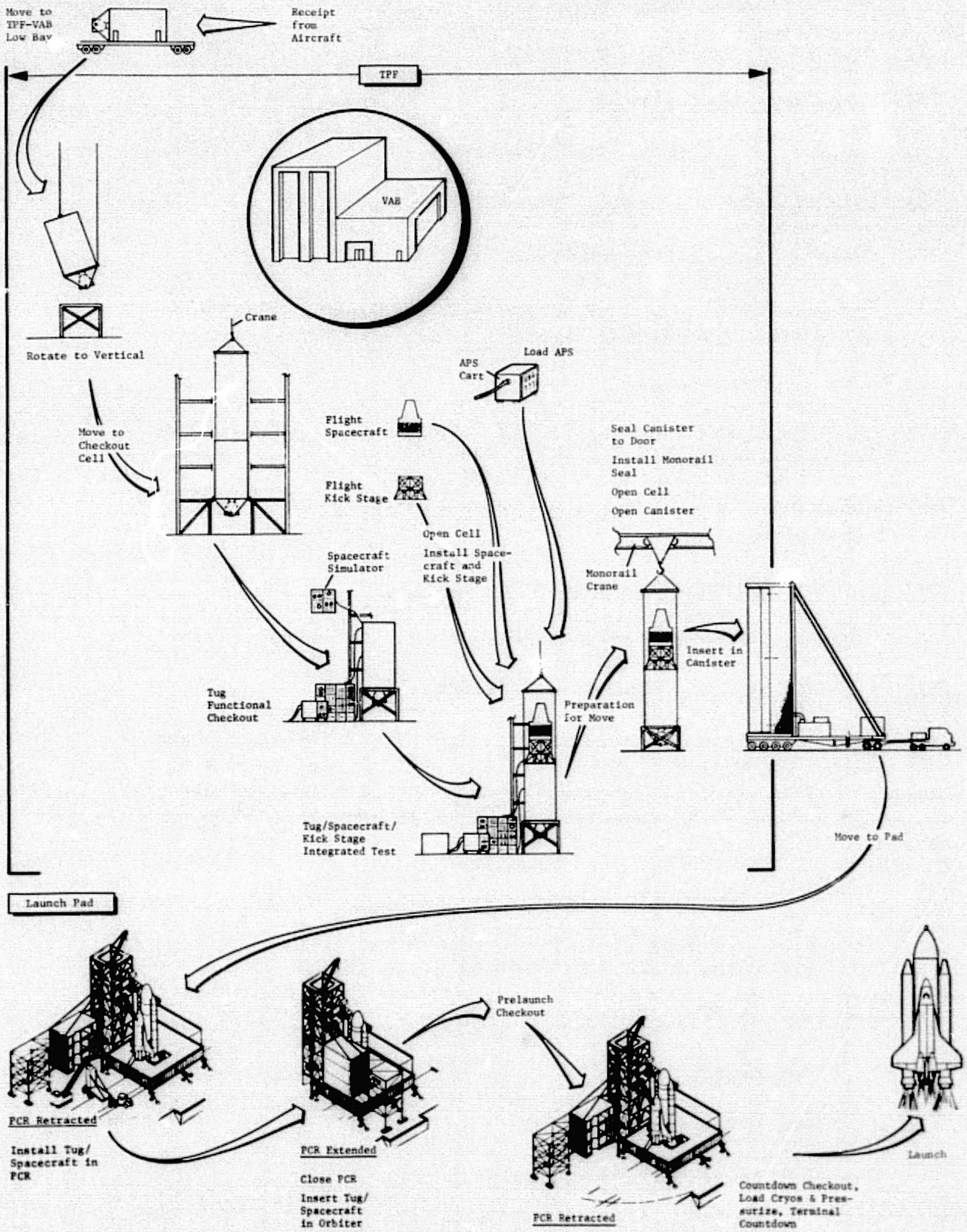

Figure III-D-33 First Flight Article, Site Activation

5) Operational checkout of the Tug in the checkout cell using the spacecraft simulator;

6) Receipt of spacecraft;

7) Spacecraft to Tug mate;

8) Tug/spacecraft integrated checkout;

9) Tug APS load and partial pressurization;

10) Canister positioned and sealed at C/O cell;

11) Tug/spacecraft inserted in canister using monorail crane. Canister doors closed;

12) Move canister to pad;

13) Open PCR, mate canister to PCR. Insert Tug/spacecraft in PCR using PCR manipulator;

14) Close PCR. Insert Tug/spacecraft in Orbiter bay. Close Orbiter bay;

15) Perform precountdown checkout;

16) Perform launch countdown, load propellants, pressurize;

17) Perform terminal countdown - launch.

3.8.10 Schedules - Planning for the Tug site activation phase was based on a go-ahead date of 1 January 1980, and launch of the first flight article in December 1983. The construction and activation schedules are the same as those in Part I of this subplan.

3.9 Ground Software Development

3.9.1 General - Ground software developed and/or used during the site activation phase includes the following:

1) Mission requirements documents;

2) Mission program tapes;

3) Checkout criteria documents;

4) Checkout program tapes and cards;

5) GSE acceptance procedures;

6) Facility validation procedures;

7) GSE installation checkout procedures;

8) Engineering model test procedures;

9) Prototype operational test procedures;

10) Maintenance procedures.

Mission requirements documents and mission program tapes will be developed jointly by NASA and the Tug contractor as a mission planning function. Checkout criteria documents will be developed jointly by NASA and the Tug contractor offsite, but used at ETR and WTR during the site activation phase. The development of this documentation and software is beyond the scope of this subplan. It is necessary to understand the basic software development process, factor in what software should have been developed by the time the Tug is scheduled to be delivered at the launch site, and determine, from a software viewpoint, what is required of the software through the site activation process. Figure III-D-34 illustrates the LPS Software Development Process and indicates responsibilities as well as how new elements enter the process.

The LPS software contractor, IBM, will probably use a top-down programming approach that develops the system level first, the model level next, etc. Each succeeding level can contain vacant or simulated modules that could be developed later. This sets up the operating system and the support system, leaving the application programs to be developed as a package at a time when more detail is available. This method does have the advantage of defining interfaces and links well enough to test groups of modules (integrated testing) shortly after coding.

This entire process will have been repeated many times and been refined in the process. Application modules will exist that perform a wide variety of routines. Spacecraft and IUS will have entered the process many times during early Shuttle era. Tug is not expected to be a large transient on the system because it will enter the program high on the learning curve. Tug software can be developed off line and verified independently of hardware. The entire Tug software process can be developed concurrently with its own hardware development.

Validation does require element hardware to eliminate large impacts at the launch site, the validation could take place at the Tug contractor's facility with a partial CCMS and telephone links to a development CDS. These preoperational engineering tests at the Tug contractor site could be used for acceptance and scientific simulation testing. Final validation/verification of the software will be done at the launch site using the Tug engineering model and the first flight article.

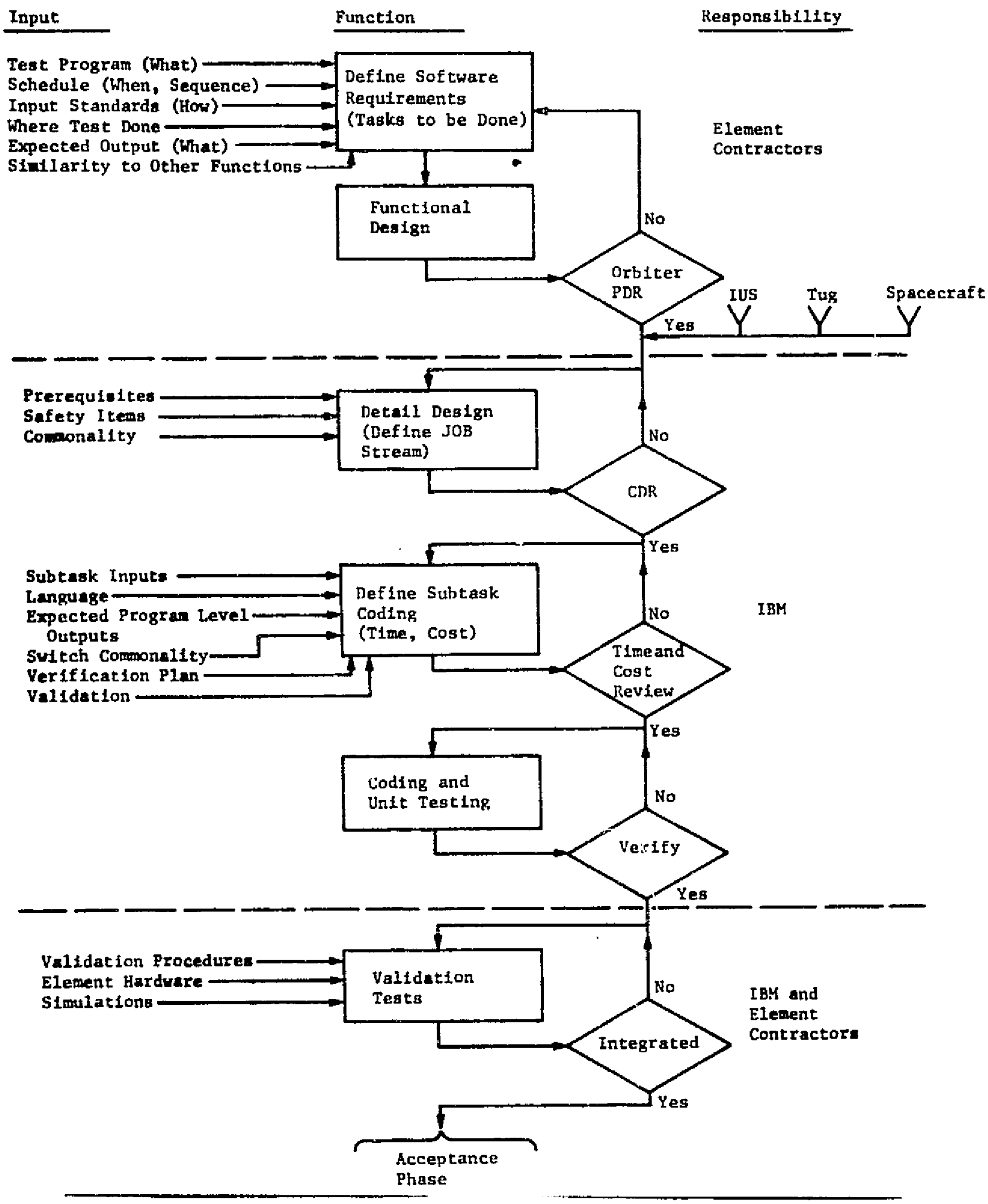

Figure III-D-34 LPS Software Development Process

The Tug checkout software development is a cooperative effort between the Tug contractor, the NASA, and IBM. The desired objective is to develop the software early, and bring it to the site integrated and validated. Software sophistication and the time allotted by the program for development lead to the conclusion that software should not be a large factor during site activation. The primary activation problems will be narrowed to hardware problems once the software has been developed.

3.9.2 GSE Acceptance Procedures - GSE Acceptance Procedures will be developed by the GSE Contractor, or the GSE subcontractor and approved by NASA. These procedures will be used at the GSE manufacturing site to verify design parameters of the individual end-item before acceptance by NASA, and before shipment to ETR or WTR.

Facility validation, GSE installation checkout, prototype operational, and operational procedures will be developed and used at ETR and WTR during the site activation phase. The development of these procedures is described in the following paragraphs.

3.9.3 Facility Validation Procedures - Facility validation procedures are normally developed by the facility construction/modification contractor to criteria developed during the A&E design, and approved by NASA through the site activation working group. Figure III-D-35 is a flow chart showing the stages in development of a typical facility validation procedure.

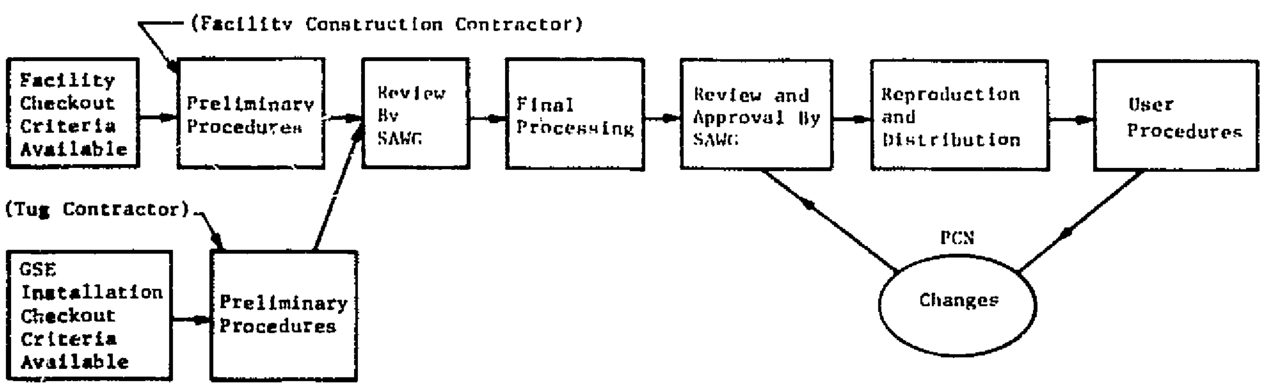

Figure III-D-35 Facility and GSE Procedure Development Flow

The procedures required to validate the new/modified facilities at ETR and WTR identified at this time are shown in Table III-D-4.

Table III-D-4 Facility Validation Procedures

Procedure No.	Facility System	Location
FVP-01-TP	Electrical Power and Ground	TPF
FVP-02-TP	Pneumatic Piping System	TPF
FVP-03-TP	Propellant Piping System	TPF
FVP-04-TP	C/O Cell Folding Platform Functional	TPF
FVP-05-TP	C/O Cell Door Functional	TPF
FVP-06-TP	Telemetry, Tracking, & Command Link (VSWR & Attentuation)	TPF
FVP-07-TP	Environmental Control System	TPF
FVP-08-TP	LPS Links and End Station Functional	TPF
FVP-01-OP	Electrical Power and Ground	OPF
FVP-02-OP	Crane Functional	OPF
FVP-03-OP	Pneumatic Piping System	OPF
FVP-04-OP	Propellant Disposal System	OPF
FVP-01-LP	Electrical Power and Grounding	Launch Pad
FVP-02-LP	LO_2/LH_2 Facility - GSE Interface	Launch Pad
FVP-03-LP	Pneumatic Piping System	Launch Pad
FVP-04-LP	Fixed and Folding Platforms (Modified)	Launch Pad (PCR)
FVP-05-LP	Launch Pad to LCC Hardline Link	Launch Pad

3.9.4 GSE Installation Checkout Procedures - Basic GSE installation tests such as wiring continuity, tubing, and pressure vessel leak checks, verification of weld integrity, etc, are performed by the installation contractor using standard industrial procedures.

End-to-end continuity tests of wiring, verification of piping systems, GSE end item functional tests, checkout of site modification to GSE, and verification of GSE to facility and other GSE interfaces will be performed at ETR and WTR by the GSE contractor using GSE installation checkout procedures. These procedures will be developed by the GSE contractor and approved by NASA as shown in Figure III-D-35.

GSE end items which are not installed, that is, portable/mobile equipment, will be functionally verified onsite using prototype/finalized operating procedures. The development of these procedures will be covered in Sections 3.9.5 and 3.9.6. The GSE installation checkout procedures required to verify installed GSE at ETR and WTR identified at this time are shown in Table III-D-5.

Table III-D-5 GSE Installation Checkout Procedures

Procedure No.	GSE System (or End Item)	Location
GSTP-01-TP	GSE Electrical Power and Distribution System	TPF
GSTP-02-TP	Guidance and Navigation Test Set (A-007) Functional	TPF
GSTP-03-TP	Control and Data Acquisition Console (A-008)	TPF
GSTP-04-TP	APS Propellant Supply & Transfer Unit, Closed Loop (P-012)	TPF
GSTP-01-LC	Control and Monitor Console (A-018)	LCC
GSTP-02-LC	Propellant Load Console (A-019)	LCC
GSTP-01-LP	LH_2 Propellant Load and Pressurization Unit, Closed Loop (P-021)	Launch Pad
GSTP-02-LP	LO_2 Propellant Load and Pressurization Unit, Closed Loop (P-022)	Launch Pad

3.9.5 Engineering Model Test Procedures - The engineering model test procedures will be developed by the Tug contractor with NASA approval. Tug refurbish and checkout procedures will be of the checklist type currently used in the airline industry rather than the detailed step-by-step procedures used in the aerospace industry today. These procedures will be used at ETR and WTR during the engineering model tests and on completion of these tests, the applicable procedures will be revised and updated to support the checkout and launch of the first flight article. The procedure development flow is shown in Figure III-D-36. The actual procedures required are identified in the functional flow of Section 3.1 and in the functional data sheets contained in Appendix A.

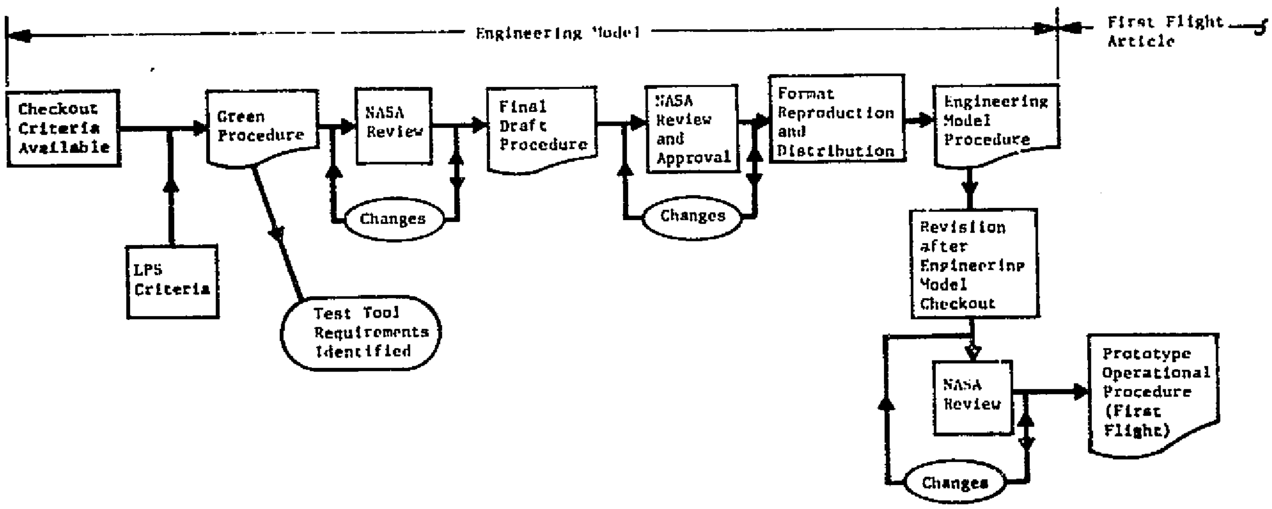

Figure III-D-36
Engineering Model and First Flight Article Procedure Development Flow

3.9.6 Prototype Operational Procedures - Prototype operational procedures will result from the procedures used in checkout of the engineering model. The first flight article Tug will be checked out, serviced, and launched using these procedures. Finalized operational procedures will develop from these procedures after update based on experience gained during processing of the first flight as shown in Figure III-D-36. The functions performed using the Prototype Operational Procedures are described in the functional flow of Section 3.1 and the functional data sheets contained in Appendix A.

3.9.7 Maintenance Procedures - Procedures for periodic maintenance will be developed by the Tug contractor for ETR and WTR with NASA approval. The analysis of maintenance requirements and preparation of maintenance procedures is covered under Logistics/ Maintenance, Section 3.10 of this subplan.

3.10 Logistics/Maintenance

The logistics/maintenance approach for factory clean Tug processing is the same as that for Class 100,000 clean Tug processing. The logistics/maintenance requirements may be found in para 3.10 of Part I of this subplan.

3.11 Configuration Management

The configuration management approach for factory clean Tug processing is the same as that for Class 100,000 clean Tug processing. The configuration management approach may be found in Subplan B.

3.12 Timeline Funding

The funding for factory clean Tug processing site activation is shown in Table III-D-6; cost of kick stage GSE and LPS equipment at ETR and WTR are included. IUS GSE will also be required at ETR, however, a survey of Transtage (IUS candidate) revealed that the required GSE was portable and could be easily relocated instead of duplicated, thus yielding no cost impact. Also included are VAB Low Bay modifications for Tug and supporting processing areas, i.e., engine preparation area, avionics checkout area, tool crib area, etc. The costs of launch pad/PCR and OPF modifications at ETR and WTR are also included.

Table III-D-6 Site Activation Timeline Funding, $ In Millions

Function	1980	1981	1982	1983	Total
Fleet Utilization Project Management	0.26	0.50	2.07	4.78	7.61
Ground and Launch Operations, ETR	0.62	1.19	2.47	19.67	23.95
Ground and Launch Operations, WTR	--	0.50	2.52	1.96	4.98
Total	0.88	2.19	7.06	26.41	36.54

The costs shown also include manpower costs. The manpower at each site is phased to reflect the program needs throughout the activation phase. The Tug Fleet Utilization Project Management Office is phased from six people in 1980 to a full staff in 1983. The ETR manpower rises from ten in 1980 to full complement by mid 1983. The WTR staffing reflects a smaller effort early in the program rising to its full time staff of seven in mid 1983. The number of WTR personnel increase after July 1983 to reflect the ETR crew of 34 TDY at WTR to check out the engineering model and the first flight article scheduled for launch in December 1983.

The detailed breakout of program costs by element and time can be found in Volume III, Program Study Cost Estimates.

4.0 Alternative Approaches

Section 3.0 of this subplan has presented criteria for a single option or approach for site selection and activation. In many cases, alternatives were available in the basic approach, i.e., low bay cell layout, area for Tug propellant servicing, etc. This section discusses these alternatives.

4.1 VAB Low Bay Checkout Cell Location

There are several possible cell configurations in the low bay; two of the most efficient are:

1) Four Cells, In-Line-West Side - This configuration was chosen in the "single option" approach adopted in the general subplan. It has the advtange of concentrating all Tug/IUS processing on one side of the low bay allowing comparatively easy sharing of facilities such as air conditioning, propellant disposal system, and storage areas. This approach leaves one side of the low bay available for other programs. Because of safety requirements for protection of vehicles in adjacent cells during tank pressurization, reinforced concrete walls or steel plates must be installed. For the four-in-line configuration, three such barriers would be required. (Each barrier would be approximately 40-ft long x 40-ft high x 10 in. (12.2 m x 12.2 m x 25.4 cm) thick concrete, or 1/4 in. (6.4 mm) thick special, perforated steel plate.)

2) Two Cells, East Side - Two Cells, West Side - This configuration limits facility sharing to a large extent. It does provide good isolation between Tug and IUS activities. It allows Tug cell activation to proceed with little interference with IUS operational processing.

Depending on whether two cells are adjacent or separated by the width of an unused cell, the safety barriers required would be either two or none. See Figures III-D-37 and III-D-38 for possible configurations.

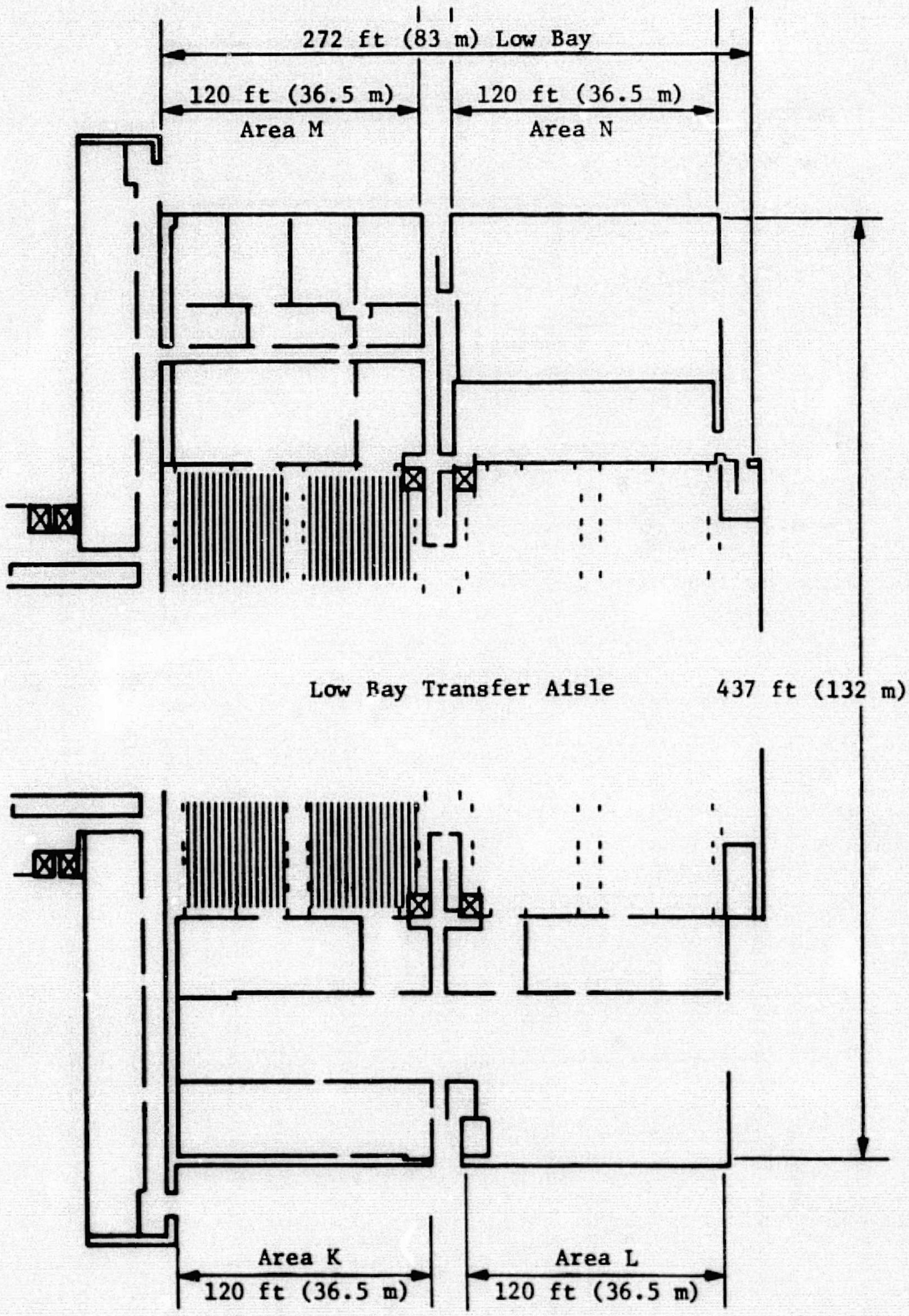

Figure III-D-37 Two Cells Each Side Concept

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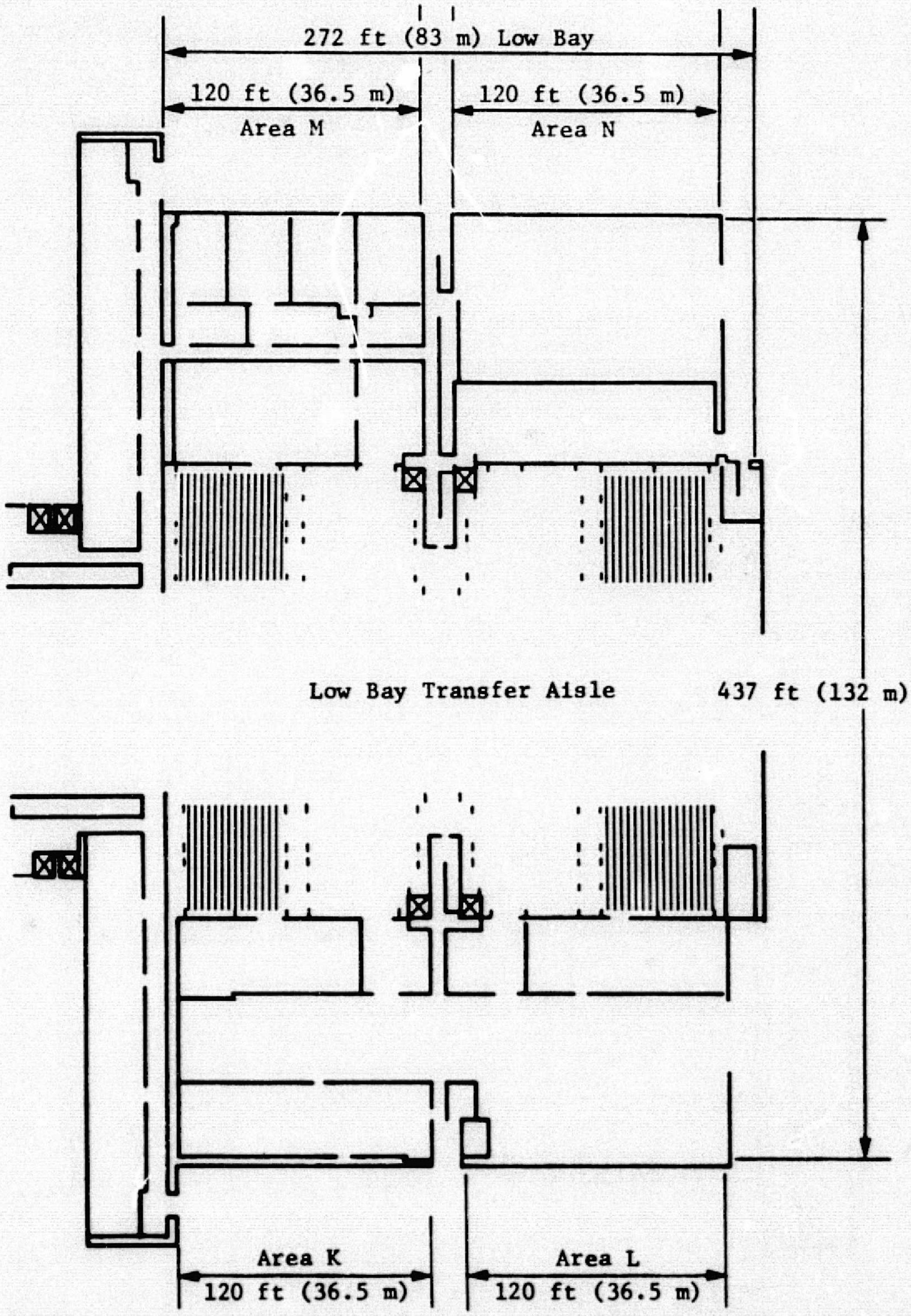

Figure III-D-38 Two Separated Cells Each Side Concept

4.2 Separate Propellant Servicing Area (PSA)

Propellant servicing, purging, pressurizing, and venting is performed in the checkout cells in the "single-option" processing of the basic subplan. This requires some form of manifolding and valving so that common pneumatic sources and vent stacks can be shared by all four cells (in the four-in-line configuration). It also requires safety barriers between cells in two of the three configurations discussed. There is also the possibility of propellant spills, constituting a potential hazard to personnel and equipment.

A separate, isolated area where all operations involving propellant handling, purging, and tank pressurization are performed, would be of great value in minimizing the potential hazards, simplifying the design of venting and pneumatic systems, and eliminating the need for safety barriers.

Use of a separate propellant servicing area would change the processing flow as follows:

1) Returned flight vehicles would be purged in the PSA (vertical or horizontal) then moved and installed in the checkout cell.

2) On completion of Tug/Spacecraft integrated checkout the combined payload would be sealed (mylar), removed from the checkout cell and moved to the PSA for APS propellant loading and and partial pressurization.

3) Transport canister would be sealed to the PSA door, and the loaded payload inserted using the monorail crane.

See Figure III-D-39 for the low bay configuration containing a propellant servicing area.

4.3 Canister Loading Inside C/O Cell

The canister loading methods described thus far involve sealing the canister to the checkout cell door and then transferring the mated Tug/spacecraft into the canister, thereby maintaining the "clean" environment during the transfer. An alternative method suggests itself by the fact that the VAB low bay cell areas are sufficiently large to accommodate both Tug/spacecraft and canister. The checkout cells will have floor areas of approximately 55x55 ft (17x17 m). The movable stands are approximately 40x40 ft (12.2x12.2 m). Assuming the canister maximum floor area to be 20x20 ft (6.1x6.1 m) (with canister vertical), it would be possible to install the canister and Tug on the movable stand in the low bay aisle, move the stand into the checkout cell, and close the doors. This would leave canister and Tug in a clean environment throughout the checkout, spacecraft mate, integrated checkout, and APS load period.

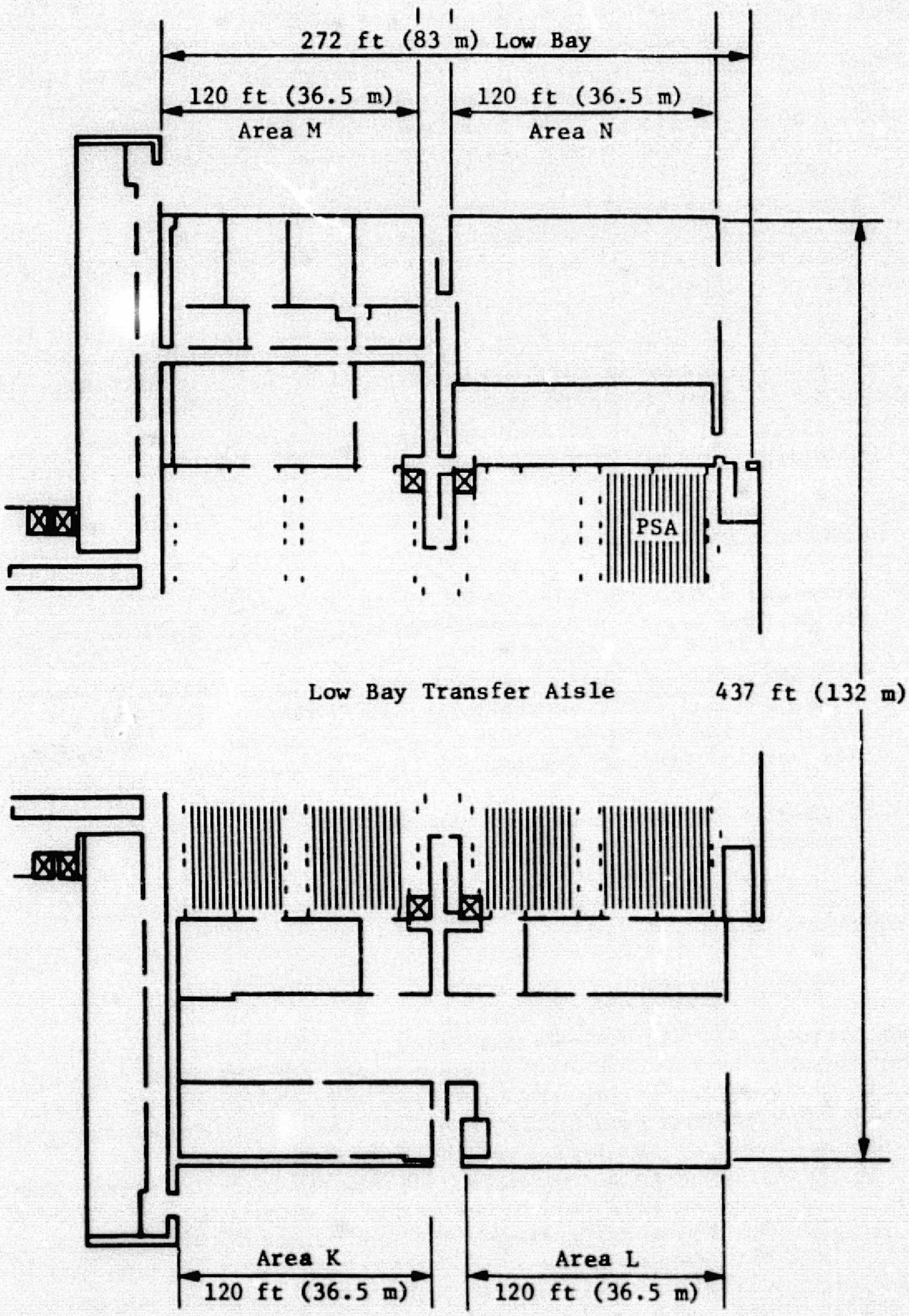

Figure III-D-39 Propellant Servicing Area Concept

The checked out and serviced Tug/spacecraft would be loaded into the canister using the overhead monorail crane. The canister doors would then be closed, the cell doors opened, and the canister moved into the low bay aisle on the movable platform. From there, it would be transferred to the transport vehicle using the low bay bridge crane. This method has some drawbacks, including the following:

1) The height of the canister will cause it to project into the spacecraft area, making environmental separation between spacecraft and Tug levels difficult. It complicates maintaining the "security-safe" provisions for the spacecraft area in two of the cells.

2) Extensive modifications to the cell platforms and mobile stand would be required for this unsual configuration.

3) It would "trap" the canister in the cell for the duration of the cell checkout period. Depending on the number of canisters allocated for the program, this may or may not be a problem.

4) Before entry into the cell, the entire canister should be cleaned. Because of space limitations, it is probable that the canister doors would have to be left open throughout the checkout period. Again, this may or may not be a problem.

Despite the drawbacks, the concept provides the important advantage of contamination-free transfer of payload to canister. It simplifies handling requirements and cell door design. The feasibility of this concept depends almost entirely on the actual canister design and the number of canisters allocated for the program.

5.0 Simulation Requirements

The simulation requirements for factory clean Tug processing are the same as those for Class 100,000 clean Tug processing. These requirements may be found in paragraph 5.0 of Section One of this Subplan.

CONTENTS

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1.0 Introduction

The IUS/Tug transition phase is that period of time when the DOD-procured Interim Upper Stage (IUS) and the NASA-procured Tug are in service. This period is currently scheduled to start with the first Tug flight in late 1983, and continue through 1984; however, this period could run as long as the Shuttle program, depending upon IUS continued use.

Transition from IUS operations to Tug operations is significant. The baseline IUS is a hypergolic propellant vehicle approximately 19 ft (5.9 m) long and 10 ft (3 m) in diameter, while the Tug cryogenic propellant vehicle is 30 ft (9.2 m) long and 14.5 ft (4.4 m) in diameter. The IUS uses rechargeable batteries for electrical power, and has no rendezvous and docking system or active thermal systems. The Tug uses fuel cells for electrical power, has rendezvous and docking capability, and has an active thermal control system. The IUS uses a kick stage for most NASA flights, while the Tug uses few kick stages. These differences, and differences in checkout approaches preclude utilization of a common IUS/Tug refurbish checkout crew. It reduces any advantage in performing Tug refurbish and checkout operations in the same areas as the IUS checkout operations are performed. These conclusions are substantiated by trade studies described in Section 5.0 of this subplan. They form the basis of some of the IUS-to-Tug transition elements discussed in Section 3.0.

2.0 General Requirements

2.1 Ground Rules

The following ground rules are applied to the IUS/Tug transition studies and to the subplan:

1) The IUS is that stage defined by NASA letter PF02-74-156 dated August 19, 1974, and McDonnell Douglas Astronautics Company, *Reference Information on Interim Upper Stage (IUS)/Satellite Interfaces for Use in IUS/Tug Payload Requirement Compatibility Study*, July 1974.

2) The kick stages used are those defined in NASA letter PF02-74-159 dated August 19, 1974, and McDonnell Douglas Astronautics Company *Definition of Kick Stages To Be Used in OOS/Tug Payload Requirements Compatibility Study*, 15 August 1974.

3) DOD will develop and provide the IUS.

4) NASA will develop and provide kick stages.

5) NASA will develop and provide the Tug.

6) All Tug processing will be accomplished at KSC. Tugs scheduled to be launched at WTR will be shipped to WTR from KSC in a near launch-ready condition.

7) All DOD payloads will be treated as secure payloads.

8) NASA and DOD payloads may be flown on either IUS or Tug, depending upon vehicle availability and mission capability.

9) NASA (or NASA contractor) will perform kick stage ground operations.

10) The IUS and the Tug will be processed vertically.

2.2 *Guidelines*

The following guidelines were developed:

1) In the pre-Tug era, DOD (or DOD contractor) will perform IUS checkout operations.

2) For non-DOD flights, DOD will provide a mission-ready IUS to the using agency.

3) NASA will perform Tug refurbish and checkout operations.

4) For non-NASA flights, NASA will provide a mission-ready Tug to the using agency.

5) Stage, IUS or Tug, processing is directed by the using agency after spacecraft-to-stage mate.

6) Stage procuring agency (IUS-DOD, Tug-NASA) will provide stage-unique crew training.

7) Stage procuring agency will be responsible for hardware (flight and unique GSE) configuration management.

8) Stage procuring agency will be responsible for logistics functions for stage and unique GSE, i.e., spares, scheduling, transportation, etc.

9) IUS and Tug refurbish and checkout instructions will be the checklist type. Personnel will be trained and demonstrate job assignment proficiency before certification as operating crew members.

10) The IUS is not a cost discriminator in selection of processing options (para. 5.2); therefore only the expendable IUS is illustrated.

3.0 IUS/Tug Transition Phase Study Elements

The Tug Fleet and Ground Operations Schedules and Controls Study requires that a standard set of 12 study elements be addressed in each subplan. Sections 3.1 through 3.12 of each subplan covers the standard elements. For IUS/Tug transition, many of the elements are either not applicable or marginally applicable, but are listed to maintain standard paragraph numbers.

3.1 Ground Operations Flow

Not applicable to this subplan. Processing flows are pro ided in subplan A.

3.2 Facility and GSE Requirements Specifications

3.2.1 Facility Requirement Specification - Those IUS/Tug facility requirements that are common to both the IUS and Tug are:

1) Checkout Area, ft^2 (m^2):	
Kick Stage	3000 (279)
2) Shop and Maintenance Areas, ft^2 (m^2):	
Avionics Checkout/Repair	750 (70)
GSE Checkout and Calibration	1190 (111)
Spacecraft Preparation to Mate	625 (58)
Tool/Equipment Crib	750 (70)
Storage	4500 (418)
Shipping and Receiving	1750 (163)
Paint Shop	750 (70)
Office Space	1750 (163)
3) PCR/Pad:	
Adjustable Work Platform, levels	3
Payload Manipulator capacity, lb (kg)	65000 (29485)
Helium Pressurization System (Piping, psig (N/m^2)	3200 (22×10^6)
4) OPF, ft^2 (m^2):	
Safe/Demate Area	9000 (836)

Because IUS and Tug use the same Kick Stage, the Kick Stage processing facility for the two stages should be the same. NASA has defined several missions requiring Kick Stages on both the Tug and the IUS (reusable or expendable). DOD has no Kick Stage requirements for missions using Tug or expendable IUS but has several missions requiring a Kick Stage with a reusable IUS. Because the Kick Stage is developed and provided by NASA (ground ruled), it is logical that one facility be used for Kick Stage buildup and checkout.

Those TPF areas that lend themselves to IUS/Tug commonality are general areas that are not affected by stage configuration or operation, i.e., areas whose common requirement is sufficient space or room to perform the function for both stages.

The PCR and pad must be designed to accommodate non-IUS/Tug payloads as well as the IUS/Tug payloads. Therefore, the facilities at the PCR/pad will be compatible/adjustable for both the IUS and the Tug. These common facilities are mainly used for IUS/Tug handling and Orbiter payload integration.

In the PCR, the ground payload manipulator must be designed to handle all Shuttle payloads, both IUS/Tug and non-IUS/Tug. The manipulator will interface with the IUS through its cradle as well as the Tug and its adapter. The access platforms in the PCR must be adjustable, along with the manipulator, to accommodate all payloads.

The OPF requires adequate room to perform the IUS/Tug safing and stage-spacecraft demating operations. An area adequate for Tug safing and demate will be adequate in size for the smaller IUS safing and demate operations.

3.2.2 GSE Requirements Specification - Because of the major differences between IUS and Tug, little GSE is common to both stages. There are, however, certain GSE items that can easily be designed to be compatible with both stages, i.e.,

APS Servicing/Deservicing Unit,
Helium Pressurization System,
Ground Payload Manipulator, and
PCR Access Platforms.

The IUS and the Tug use N_2H_4 as the APS propellant and the systems are similar in some other respects, such that by using interface connectors a single APS servicing/deservicing unit could be used. Both stages also use helium for main propulsion pressurization; this helium interface could be common for both the IUS and the Tug.

3.3 Transportation Requirements and Support

The concept of 747 piggyback transport proposed for Tug can be applied to the IUS. Air offers obvious advantage of rapid IUS delivery from the manufacturer to KSC or return to KSC from alternative or contingency landing sites. Although other aircraft, including the C-5A, will accommodate the IUS, there is economic advantage in multiple use of the 747, the cargo canister, the Mate-Demate Facility and other items of transportation support equipment. Availability of other aircraft and the scheduling load placed on the 747 for Orbiter, External Tank, Tug, spacecraft and other Shuttle transportation will of course affect the IUS transport

decision. Although not as restrictive for the 10 ft (3m) diameter IUS as for Tug, over-the-road transport by trailer or van would still require added time and special route considerations.

Applying the 747 concept, various items of TSE used in the ground handling and air transfer sequences can be designed for common application to the IUS and Tug. The IUS can be carried in the cargo canister through use of its cradle in the same fashion as it will be carried in the Orbiter payload bay. Based on early availability, the MDF can be used to handle canisters for IUS shipments as well as Tug shipments. The cargo canister transporter can be used for IUS as well as Tug ground movements to the airfield at KSC as well as between the IUS processing facility and the pad. Airborne instrumentation to monitor and record shock, vibration, temperature, humidity, and pressure can be designed for common application to IUS and Tug.

3.4 Operational Data Requirement

Not applicable to this subplan.

3.5 Manpower Staffing

Because of the dissimilarity of the majority of IUS and Tug systems, there are few common operations. As the IUS or Tug nears completion of the refurbish/checkout cycle, the stage operations (system level) tend to become more common.

Two areas of crew operations similarity are APS servicing and helium pressurant servicing. Since both stages have a similar APS and He pressure systems, personnel could be certified to perform these operations on the IUS and the Tug. Another area is handling of the IUS and Tug when it is in the payload canister or the 747 cargo canister. The handling operations of the IUS and Tug after delivery to the pad and removal from the canister will be similar through installation in the Orbiter cargo bay. These handling operations could be done by a common crew certified to handle both stages.

Because of the basic system differences between the IUS and the Tug, it appears that separate refurbishment/checkout crews should be used for the IUS and Tug. Because IUS is used less than Tug during the transition period, the number of Tug certified personnel would be greater. The traveling launch crew need only be certified for Tug because only Tugs will be flown from WTR.

Individual certification and skill certification (soldering, potting, etc.) have some commonality that would apply to operations on either IUS or Tug.

Recognizing that both NASA and DOD may use residual IUSs after 1983 (if the IUS is retained) and that NASA will be involved to an extent in management of the IUS fleet, the manpower impact during transition period is keeping a two-crew capability (IUS and Tug) and a contingent of fleet management personnel. A WTR Tug Office will also be maintained during the transition. Figure III-E-1 illustrates the impact of transition on the manpower requirements. The IUS ground operations crew size for the IUS is based originally on the data from Vol. 6 of the Space Tug Systems Study (Storable), September 1973, by Martin Marietta Corporation and extrapolated down from the stick and ball chart (Figure III-A-2) in Subplan A. The fleet management requirements are extrapolated from the organization chart (Figure III-B-14) of subplan B.

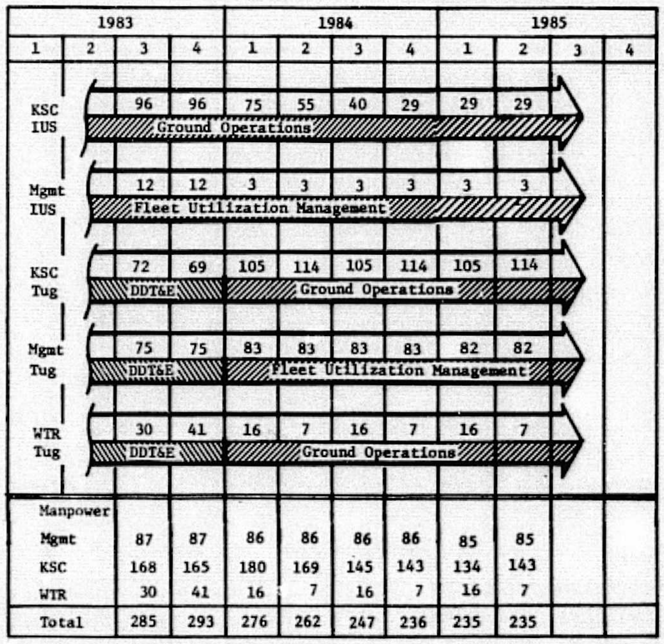


Figure III-E-1 Manpower Requirements during IUS to Tug Transition

3.6 Safety Requirements and Support

The general safety requirements for the Tug and the IUS are similar because both stages will be involved in hazardous ground operations. The IUS/Tug processing functions include handling, transportation, propellant transfers, and pressurant transfers that are commonly considered to be hazardous operations. Configuration differences, however, dictate some specific safety requirements peculiar to each stage. Procedural constraints for hazard control must be incorporated into definitive operating procedures that will be stage peculiar.

Hazardous operations that are common to both the Tug and IUS include APS servicing, pressurization system servicing, transportation, and handling. Both stages use monopropellant hydrazine for APS, which is toxic and flammable. Helium pressurization systems are used on both stages for MPS pressurization; GN_2 is used for IUS ACS pressurization, and the Tug APS uses helium. Both inert gases present pressure energy hazards at the operating pressures up to 3200 psi (23×10^6 N/m^2). All vehicle transportation and handling functions represent accident potentials. Requirements for safe handling of vehicles, hydrazine, and pressurants are well established and must be applied to specific operating procedures. The same operating crew training and certification requirements apply to both stages.

The different characteristics of main propellants used by the Tug and IUS require specific safety requirements for each. Again, the requirements for safe handling of both cryogenic and storable propellants are well established and are being applied to vehicle, GSE, and facilities designs. The predominant safety requirement to isolate incompatible fluids to the maximum practical extent leads to different MPS servicing approaches. Material incompatibility problems dictate separate GSE/facility equipment. Operational constraints required for hazard control will be incorporated into the stage-peculiar operating procedures. The differences in propellant characteristics require separate training and certification for propellant handling crews.

Separate processing areas for the IUS and Tug are required to comply with the general safety requirements. As a minimum, the separation may be dedicated cells within a building. Configuration differences require separate safety approved operating procedures for each vehicle even for common operations such as APS servicing. This requirement is caused by conditions such as component locations and designations. Common crew training and certification is possible for some functions, such as handling and APS servicing, but not for stage-peculiar functions.

3.7 Fleet Utilization and IUS/Tug-to-Payload Integration Requirements

Not Applicable to this subplan.

3.8 Site Activation and Verification

The Tug Site Activation subplan, contained in Section D of this volume, provides an activation plan for two facilities at ETR.

1) SAEF-1 for Tugs processed clean.

2) VAB low bay for Tugs processed uncleaned.

The SAEF-1 building could be modified and activated for Tug processing if it is available for modification no later than January 1, 1980. This would be a significant modification affecting the entire structure. If it is decided to process the IUS in this building from 1980 through transition, it would be undesirable to modify the building for Tug operations because of the interference to IUS operations and Tug modifications. Therefore, the modification of this building for Tug processing is based on the premise that IUS operations are accomplished in another area. There is adequate space in this building to provide a cell for IUS to spacecraft mate. However, again assuming that IUS-S/C mate has been accomplished in an IUS facility before 1983, it appears that it would be better to continue IUS mate at the IUS facility throughout the remainder of the program.

The VAB low bay also requires extensive modifications to adapt it for Tug processing operations. However, because of the size of the facility modification, work can be accomplished without interfering with ongoing Shuttle operations. Because of facility layout, it would be possible to modify one area of the low bay for IUS checkout, and then modify the other side for Tug operations without interference with either operation. Since clean buildings may be in high demand for spacecraft operations, the VAB appears to be a better place to process the Tug from a total Shuttle program standpoint. The results of an analysis of Tug processing in an unclean environment indicate that uncleaned processing in a "factory clean" area is the favored approach. Therefore, the VAB could be effectively used for Tug processing and would provide the option for IUS processing in cells on the opposite side of the transfer aisle.

In either case, SAEF-1 or VAB low bay, the transition rom IUS to Tug processing from a site activation standpoint is not so much a transition but an activation of a totally new facility--a facility configured for a larger cryogenic reusable Tug versus a facility configured for a smaller hypergolic expendable IUS. Different checkout/procedures will be required, a different GSE concept will be used, i.e., Tug uses LPS to maximum, IUS uses existing GSE for checkout. Section 5.0 of this subplan addresses the commonalities between the Tug and the IUS with the conclusion that there is little commonality. Therefore, there will be little transition, per se, and more likeness of activation of the new facilities and operations.

3.9 Checkout Ground Software Development

To develop software philosophy during the IUS to Tug transition phase and determine common areas of usage, usage rates, and update approaches, the background of the IUS and its expected software must be examined. Only after the IUS software approach is understood can the transition aspects be appreciated.

The IUS is presently involved in a definition phase without specific guidelines to use LPS. Existing hardware and software will probably be used to keep the costs down. There are advantages for DOD to remain independent through the early period of the Shuttle program. These are: (1) slips in the LPS development may deprive them of GSE hardware and software when they need it; (2) it is easier to integrate self-contained packages; (3) costs are more predictable; (4) DOD will not be materially affected by LPS development, debugging, and activation; (5) priorities may affect initial LPS acquisition; and (6) risk is materially reduced with working systems. Therefore, it is assumed the IUS will have its own GSE and software.

Spacecraft are expected to have even more variable GSE and software throughout the early part of the Shuttle program. Those spacecraft using IUS or Tug will be primarily NASA payloads that will use either LPS or existing GSE and software. Wherever the spacecraft is mated and tested with IUS, kick stage or Tug, the combined testing will marry dirverse elements, and eventually the entire combination will reach the launch pad and Orbiter. At the launch pad, from T-4 to liftoff, LPS will be used; before T-4, use of combinations of dedicated GSE, airborne computers, and LPS is possible.

There are some areas of commonality of software usage. Certainly T-4 to liftoff uses common LPS software. Looking ahead in the mission predeployment and postdeployment testing, updates, monitoring, controls, and displays will use software developed for the onboard computers. Most of these orbital operations are exercised before liftoff. When the IUS or Tug is mated with a possible kick stage and spacecraft for the first time, part of the combined systems testing will include exercising these later routines with missing Orbiter computers being simulated.

Another area of possible common software usage is simulating various Orbiter parameters or functions to the IUS, Tug, kick stage, or spacecraft during element subsystem testing. These subroutines could be developed and called up during any and all testing not involving an Orbiter.

Most payload software will be modular in form with test sequences putting together the modules. In a modular form, these subroutines will be easier to modify, test, and verify offline before tests start. New operations or updates will simply create new software building blocks.

During the transition phase from IUS to Tug, it appears that every possible combination of old and new software will exist. The software system will have to respond to every kind of demand or request possible. The user will have the best insight into his own requirements and probably do his own software requests. The LPS software contractor will standardize many different requests

and consciously maintain software commonality throughout the program. The transition phase transfer from IUS to Tug will not be a big step function because of previous development and partial and dual usage.

3.10 Logistics and Maintenance

The various elements of logistics support will vary widely in application between Tug and IUS based primarily on major differences in size, component configuration, and the reusability aspects of Tug versus IUS.

The logistics management function will be concerned with entirely different approaches to such areas as spares procurement and maintenance planning. A system of deferred spares acquisition will be a necessity on the reusable Tug to hold down initial provisioning cost and defer spares decisions until refurbishment experience is gained. An expendable IUS will not require these considerations and will use critical item spares only to cover preflight operations. Maintenance planning for postflight refurbishment flow will not be required for an expendable IUS. The process of support requirements analysis will be far more extensive on Tug and will be vitally concerned with reusability requirements. Of course, if the IUS is reusable, the approaches will be similar.

Maintenance and repair activities differ considerably because of configuration differences. LRUs will differ not only in configuration but in location and access provisions, and Tug LRU postflight implications are vastly different from IUS. Tug maintenance activity will be planned with heavy reliance on operational flight instrumentation to target maintenance activities in the Post Flight Maintenance Activity Plan. GSE/TSE and its required maintenance and spares, will differ except for possible design common items like APS servicing/deservicing unit, the He pressurization system, ground payload manipulator and PCR access platforms.

Common warehousing of spares, bulk items, consumables, etc, has as its only feature multiple use of a facility. Tug and IUS inventories should not be mixed but kept physically separated to preclude problems of DOD and NASA inventory system discrepancy as well as errors in statusing and issuance.

Training, for the most part, will be peculiar to each stage. No common crew application is foreseen based on configuration differences, especially in the propellant area. Probable overlap in Tug and IUS processing schedules further supports a requirement for separate crews. Shared training between the using agencies in common areas like APS, common GSE, and handling would be beneficial and would add depth to the number of available personnel for team operations. As mentioned earlier in this subplan, skills training is also a probable and practical possibility.

Operational technical documentation requirements are seen as unique to each stage. Basic configuration differences, and location differences even on common equipment, plus the different change cycle impact on the documentation, indicates necessity for separate stage O&Ms, OMIs, etc.

In the transportation and handling area, the 747 carrier aircraft and piggyback canister concept can be used for both Tug and IUS with all the resulting commonality benefits. However, the 10-ft (3-m) diameter IUS can be carried as internal cargo on a variety of other aircraft to reduce the scheduling impact on the 747, which may transport Orbiter, External Tank, a wide variety of spacecraft and multisupport equipment. If aircraft other than the 747 is used for IUS transportation, TSE and transportation and movement plans will differ for Tug and IUS.

The best, and in final analysis the most cost effective, logistics approach for Tug and IUS is one of separate programs and separate control with shared commonality as appropriate.

3.11 Configuration Management

The configuration control system established in subplan B, should be adapted to the IUS program and used to control Tug configuration. The configuration control board established in that system will review and approve/disapprove design changes made in response to technical problems, or as a result of changes to mission or Shuttle requirements. Since the IUS procurement agency is also the agency responsible for managing all DOD spacecraft, they should be a member of the Tug CCB as NASA should be a member of the IUS CCB because they are the responsible agency for NASA and NN/D spacecraft carried on the IUS. A balanced (intraagency and contractor) change control procedure should be used to establish effective controls and preclude any unauthorized changes to IUS or Tug specifications.

Traditionally, schedules have been geared to flight hardware readiness, and management visibility has been concentrated on flight hardware and software test and checkout. Historically, the ground software has been the pacing item because of lack of early planning, parallel development with the flight hardware/software, lack of compatibility analyses, and management emphasis being withheld until the ground software was in trouble. Software is no different than hardware with respect to planning, implementation, delivery, scheduling, test and checkout, problems resolution, etc. The CCB must recognize this and place equal emphasis on flight and ground software requirements and changes, along with hardware changes.

These procedures (subplan B) will ensure that each proposed hardware or software change is thoroughly coordinated with all involved agencies, reviewed, evaluated, and acted upon. This process and involvement of government agencies and contractors will assure a smooth transition from the IUS to Tug operations.

3.12 Timeline Funding

The costs for modification and activation through first flight article checkout and launch are included in subplan D, Tug Site Activation subplan. In subplan E, the costs of maintaining IUS and Tug capability during a transition period of one year (1984) were addressed with residual IUSs after 1984 for a few missions. Therefore, the NASA cost impact in this transition period is one of keeping a two-crew capability (IUS and Tug) at KSC, a fleet management contingent, and a Tug Office at WTR.

Because there are currently two Tug launches from WTR in 1984, one being the WTR first flight article Tug, there will be a period of about three weeks and one of about two weeks, where 34 personnel from KSC will be TDY at WTR to support these launches. Since the launch dates have not been established the TDY shown in Figure III-E-1 is in the first quarter.

Table III-E-1 reflects the quarterly Tug costs of the transition period and includes costs of transfer of personnel between ETR and WTR to support WTR launches. Other Tug costs such as propellants, computer time, and maintenance subcontracts are spread evenly throughout the year. Costs for flight hardware and GSE spares are added to the first quarter costs for the year they are expended. These costs also include the costs of IUS personnel shown in Figure III-E-1.

Table III-E-1
Tug Ground Operations Quarterly Funding ($ in millions)

Time / Activity	1983		1984				1985	
	3	4	1	2	3	4	1	2
Tug Project Management	1.19	1.19	3.34	1.28	1.32	1.28	3.65	1.28
Tug KSC Operations	0.69	0.66	2.26	0.85	1.09	0.35	2.55	1.19
Tug WTR Operations	0.48	0.59	0.40	0.09	0.26	0.09	0.33	0.09
TOTAL	2.36	2.44	6.00	2.22	2.67	2.22	6.53	2.56

4.0 Critical Procurement Problems

4.1 Construction Phase

Availability of construction material has decreased over the past year and some items are in short supply. Construction material that has in the past been known as "in-stock" material has now become semi-long-lead material because of resource shortages. Affecting items in this category are:

Wire - 30 days minimum lead
Pipe and Tubing - 45 days minimum lead
Structural Steel - 45 days minimum lead
Aluminum Shape - 45 days minimum lead

Former long-lead material has now become longer lead time items. Impacting items in this category are:

Cable (special lay) - 6 months
Mechanical Components - 6 months
Explosion Proof Electrical Hardware - 5 months

It is not anticipated that there will be an improvement of these lead times in the 1980 to 83 time period. Therefore, early identification of material requirements for Tug operational facilities is necessary.

4.2 Activation - Verification Phase

Assuming a Tug facility preparation go ahead of January 1980, and the launch of the first flight Tug in December 1983, Table III-E-2 indicates the availability requirements.

Table III-E-2 Activation-Verification Availability Requirements

	1980	1981				1982				1983			
	4	1	2	3	4	1	2	3	4	1	2	3	4
Availability Requirement													
Sites													
SAEF-1 Mods (100K)	▼												
VAB Mods (Factory Clean)		▼											
PCR/PAD Mods		▼											
OPF Mods			▼										
SAEF-1/VAB Rdy for EM C/O										▼			
PCR/PAD Rdy for EM C/O											▼		
<u>Equipment</u>													
GSE					▼								
Engineering Model										▼			
Dummy S/C & Kick Stage										▼			
Canister/Transporter											▼		
Orbiter Rdy for EM C/O											▼		
First Flt Article at ETR												▼	
First Flt S/C & KS at ETR												▼	

More detailed schedules for Tug site activation, engineering model checkout and the first flight article flow can be found in the Tug Site Activiation Subplan, Subplan D.

It should be noted that the PCR/pad is required for start of modifications in February 1981, and again for activation checkout in April 1983. An Orbiter is also required to facilitate activation in 1983. These later dates are in the peak period of IUS flight activity and will require close coordination between the IUS and Tug projects, and the other elements of the STS program.

5.0 Joint Usage Assessments

5.1 IUS/Tug Hardware Commonality Assessment

It has generally been assumed that there are advantages to providing a common IUS/Tug processing facility. This is based on an objective to "maximize" the use of common IUS and Tug GSE, facilities and other launch operations for the IUS to Tug transition. However, in order to determine objectively the desirability of processing the IUS and Tug together, the commonality between IUS and Tug operations must be investigated. The main thrust of this commonality survey was in refurbish and checkout facilities and GSE requirements. This survey revealed certain facilities and GSE that were very similar to TUG and IUS operations. These similarities, considered early in the program, could result in designs for common usage.

The TPF areas of IUS/Tug commonality are primarily LRU and GSE checkout areas and shop areas that are not sensitive or dedicated to the type of hardware processed in that area. These are tool or equipment cribs, paint shop, avionics checkout and maintenance, GSE checkout, calibration and maintenance, shipping and receiving, component cleaning, stage storage, etc. Other activities that can be consolidated are the IUS and Tug engineering support offices and APS servicing area.

Because of the difference in size of the Tug and IUS (Tug - 14.6 ft (4.4 m) diameter x 30 ft (9.2 m) long; IUS - 10 ft (3 m) diameter x 19.2 ft (5.9 m) long) two different refurbish and checkout cell sizes are required in the TPF. It is possible to make cells convertible to either Tug or IUS; however, time to convert and the traffic model indicate that the best approach would be to provide two Tug cells and one IUS cell in a combined facility to support the NASA and NN/D traffic. Again, because of the difference in vehicle and subsequent engine sizes and manufacturer, two engine refurbish/checkout areas are required. Since the engines are different, there is no commonality of engine spares or procedures.

The TPF airlock will require two work stations, one for Tug and one for IUS to deservice, clean, and leak check the vehicle. Because of the size difference, the GSE workstands to accommodate the Tug and IUS will be different. The Tug will require a hydrogen burn stack and an external oxygen vent while the IUS will require oxidizer and fuel vapor combustion units. Space allocation for checkout GSE will be different for the Tug and IUS. The Tug will use the LPS for checkout and monitoring, requiring an LPS station in the checkout area. Current IUS planning indicates that van mounted GSE will be used for checkout. The van will be located external to the TPF and GSE cables will be connected via a building wall mounted feed-through.

The servicing/pressurization GSE supporting the Tug and IUS will be different. The Tug MPS operating pressure is 17 to 18 psia (11.7×10^4 to 12.4×10^4 N/m^2) while the IUS MPS is a 160 psia (1.1×10^6 N/m^2) system. This GSE would also be procured by two government agencies from their respective contractors. Fuel cell reactants servicing GSE would be peculiar to the Tug, while APS servicing/pressurization GSE could be made common for both stages since the propellant is the same. The handling GSE will be different because of the different vehicle diameters and lengths.

Since the type of kick stages currently identified for the Tug are the same as those used by the IUS, the kick stage buildup/checkout area can be common for the IUS and Tug. This is especially true because the kick stage is assumed to be developed by one agency for use on both stages. The current traffic model requires only nine Tug kick stages during the life of the Shuttle program. The IUS requires a larger quantity of kick stages.

The PCR IUS and Tug work platforms would be a part of a total payload platform set. Those platforms to be used by the IUS and Tug should be designed to be adjustable and interchangeable. The ground payload manipulator will be common to IUS, Tug, and non-IUS/Tug payloads. Both the IUS and Tug use helium in their pressurization systems. Therefore, the PCR/pad helium supply/service system to the Orbiter interface can be a common system. The Tug will require two major additions to the PCR/pad, the cryogenics loading system for Tug and the fuel cell reactant loading for Tug fuel cells. The IUS would not require either of these systems at the pad.

There are no IUS operations in the OPF, abort excepted, for an expendable IUS. In case of a resuable IUS, the IUS/Tug operations in the OPF would be very similar. Any area large enough to accommodate planned Tug operations will be adequate for the planned IUS operations. In the OPF, the Tug would require a hydrogen burn system and external oxygen vent system. Neither system would be common with IUS MPS facility vent system. Two T-0 interface

panels will be required, one for the cryogenic vehicle and one for the hypergolic. The handling GSE required to remove the payload from the cargo bay will be different because of size differences between Tug and IUS. The deservicing GSE used in the OPF will vary depending upon vehicle propellants.

The LCC would require consoles and racks that are unique to the IUS and unique to the Tug for propellant loading and systems monitoring. Therefore, sufficient area is required in the LCC for both the IUS and Tug propellant loading and system monitor consoles/racks.

Table III-E-3 summarizes results of the commonality assessment for facility and GSE impacts and other considerations, i.e., schedules, software ground checkout, crew considerations, safety and fleet utilization/management concept having commonality impacts are shown in Table III-E-3.

Table III-E-3 Commonality Assessment

Item	IUS	Tug	Commonality
Checkout Cells	(1) 25 x 25 ft (7.5 x 7.5 m) with 10 ft (3 m) cutouts	(2) 35 x 25 ft (10.6 x 7.5 m) with 15 ft (4.5 m) cutouts	Could conceivably be made common with adjustable cutouts and platform levels with some penalty.
Service/Deservice/ Pressure GSE (MPS)	Hypergolic Set	Cryogenic Set	No commonality
Transportation and Handling GSE	Accommodate 10 ft D x 19.5 ft L (3 x 5.9 m)	Accommodate 15 ft D x 30 ft L (4.5 x 9 m)	Possibly adjustable for commonality but may result in cost penalty rather than advantage.
Avionics Checkout GSE	Van Mounted GSE	Primarily LPS	No commonality
Orbiter Fluid Interfaces	Hypergolic	Cryogenic	No commonality
Kick Stage Checkout Areas	Solid, 2 Sizes	Solid, 2 Sizes	Common
Engine Checkout and Service Area	30 x 30 ft (9 x 9 m) Hypergolic	25 x 25 ft (7.5 x 7.5 m) Cryogenic	Could possibly have some common capabilities
LCC	IUS Unique	Tug Unique	No commonality
Site-to-Site Transportation Equipment	747 Canister, MDF	747 Canister, MDF	Joint usage

Table III-E-3 Commonality Assessment (con't)

Item	IUS	Tug	Commonality
Schedules	IOC Dec 1983, Variable Launch Rate thru 1991	IOC 1980, Heavy Traffic to 1984 Transition, Sustaining Low Level Traffic 1991	Little compatibility, Tug facility modifications and activation during heavy IUS traffic period.
Software, Ground Checkout	LPS Unique Software	Van Mounted Cage-Type System	No commonality
Crew Considerations			
Crew Skills	Cryogenic/Avionics	Hypergolic/Avionics	Some commonality in avionics skills.
Crew Training	Individual and Crew Certification for Tug Unique Systems	Individual and Crew Certification for IUS Unique Systems	Little crew certification commonality. Some common individual certification
Safety	Cryogenics, Hydrazine (APS), Fuel Cell, Handling	Hypergolics, Hydrazine (APS), Batteries, Pyrotechnics, Handling	Common safety requirements for handling and APS servicing.
Fleet Utilization/ Management Concepts	Moderate Active and Total Fleet, Significant Spares Inventory 7-8 Years Operation. NASA "Paper" System	Small Active/Total Fleet Small Spares Inventory, Heavy Traffic 3 to 4 Years Only. DOD "Paper" System	Some common systems possible.

From this summary it is apparent that there is little advantage to a combined IUS/Tug processing facility with respect to commonality other than the facility enclosure itself. Therefore, it would not be cost effective to force-fit an IUS refurbish/checkout cell into a Tug facility just to gain IUS capability unless some other advantage becomes apparent. On the other hand, there is a great deal of commonality in support areas, shops, kick stage processing area, storage/warehousing areas, engineering and office areas. There is some commonality in the management systems used by the two agencies procuring the IUS and Tug. Table III-E-4 summarizes these commonalities and conclusions.

Table III-E-4 Commonality Assessment - Conclusions

LITTLE COMMONALITY IN:

Processing Facility Requirements
Checkout Equipment Concepts
Servicing Equipment
Crew Considerations
Schedules
Software

SOME COMMONALITY IN SUCH THINGS AS:

Safety Considerations
Fleet Utilization Management
Support Shops
Kick Stage Processing
Storage/Warehousing

CONCLUSIONS:

Little Apparent Advantage To A Common IUS/Tug Processing Facility

RECOMMENDATIONS:

Don't "Force Fit" IUS Into Tug Processing Facility

Consider Common Support Shops, Storage/Warehousing, Kick Stage Processing, Management Systems

5.2 *IUS/Tug Operational Joint Usage Assessment*

5.2.1 General - In order to determine and evaluate the effects of IUS to Tug transition, some additional basic ground operations approaches must be established, namely, the approach to IUS checkout and Tug refurbish and checkout, kick stage checkout, IUS/Tug to spacecraft integration and payload to Orbiter integration. To effectively plan for the transition period, the agencies having responsibilities toward these functions must also be identified.

To establish a basis for the IUS to Tug transition subplan approach, numerous approaches of IUS-Tug operations were considered. Through a selective process these approaches were reduced to seven options:

NOTE: Clean Tug Processing = Processing a 100K clean Tug in a 100K clean facility
Uncleaned Tug Processing = Processing an uncleaned Tug in a "factory clean" facility

1) Clean Tug processing in dedicated facilities;

2) Clean Tug processing, spacecraft mate in user facility;

3) Clean Tug processing, PCR mate option;

4) Uncleaned Tug processing, spacecraft mate in separate integration facility;

5) Uncleaned Tug processing, single security area for DOD payloads;

6) Uncleaned Tug processing in joint IUS/Tug facility;

7) Uncleaned Tug processing, separate IUS and Tug facilities.

These seven options are further discussed herein from the standpoint of launch site facility and GSE requirements. In all seven options, there are three common considerations that impact the ground operations philosophy.

1) DOD is responsible for IUS development and procurement;

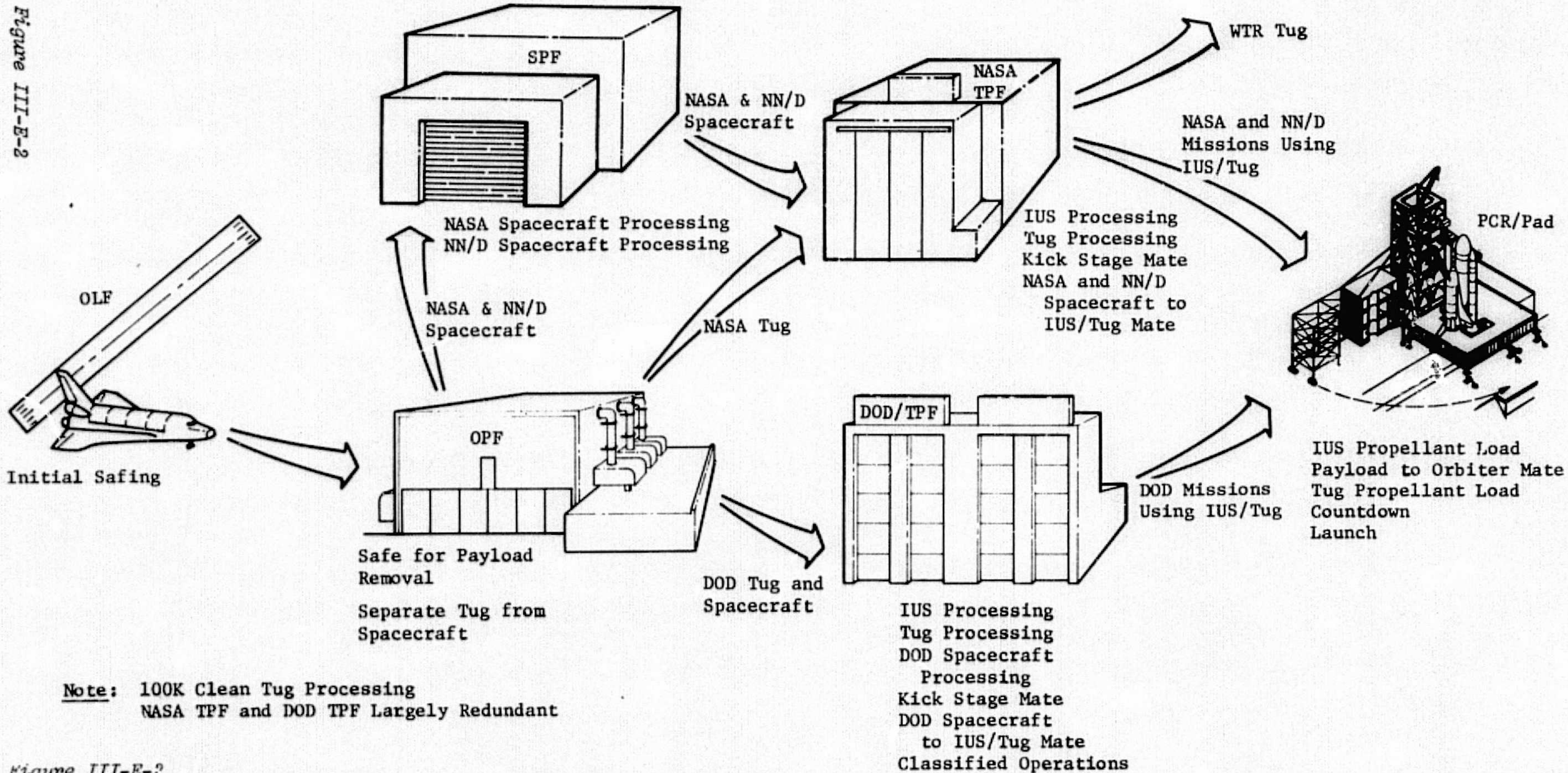
2) NASA is responsible for Tug development and procurement;

3) NASA is responsible for kick stage development and procurement.

These considerations affect ground operation in that the agency responsible for development and procurement of the stage is also responsible for the procurement, provisioning, and inventory management of flight vehicle spares, the GSE and GSE spares, GSE maintenance, the logistics system, crew training and certification, checkout procedure preparation, revision and update, GSE and checkout software preparation and update. These factors, plus the DOD security requirements, have been included in the evaluation and reduction of the approaches considered to the seven options selected to be further discussed.

5.2.2 Option 1, Clean Tug Processing in Dedicated Facilities - Figure III-E-2 depicts the IUS, Tug, and kick stage flight hardware flow for this Option. Upon return from a mission, the Tug is removed from the Orbiter and separated from the spacecraft in the OPF; the DOD Tug is moved to the DOD refurbish/checkout facility and the NASA Tug to the NASA facility. Vehicle cleaning and stage processing then occurs in the duplicate TPFs. Kick stages are provided as required, clean and fully checked out, from the kick stage processing facility. The payload is built up, Tug and spacecraft, or Tug, kick stage and spacecraft, and integrated tests performed. The payload is then installed in the payload canister and moved to the pad for Shuttle integration, testing, and launch.

This approach provides two parallel paths for IUS/Tug processing; it also requires two complete facilities, sets of GSE, and operating crews. All IUS/Tug secure operations can be performed totally within the DOD facilities with the exception of those secure operations required at the PCR/pad for prelaunch and the OPF for postlaunch operations. Table III-E-5 provides a summary of facility and GSE requirements for this option.



<u>Note</u>: 100K Clean Tug Processing
NASA TPF and DOD TPF Largely Redundant

Figure III-E-2
Option 1, Clean Tug Processing in Dedicated DOD and NASA Processing Facilities

Table III-E-5 Option 1 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF
Secure Area		x	x	x	
LPS Terminal	x	x	x	x	x
Clean Area (Bldg)	x	x	x		x
Airlock	x	x			x
Tug Unique GSE					
Avionics	x	x			
Handling and Transport	x	x		x	
Propulsion and Mechanical	x	x		x	
Structural	x	x			
Tug Facilities					
Engine Area	x	x			
Avionics Area	x	x			
H_2 Burn System	x	x		x	
O_2 Vent System	x	x		x	
GSE Area	x	x			
Airlock Station	x	x			
APS Load System	x	x			
IUS Unique GSE					
Avionics	x	x			
Handling and Transport	x	x		x	
Propulsion and Mechanical	x	x		x	
Structural	x	x			
IUS Facilities					
Engine Area	x	x			
Avionics Area	x	x			
Vapor Disposal System	x	x		x	
Checkout and Mate Cell	x	x			
GSE Area	x	x			
Airlock Station	x	x			
APS Load System	x	x			
Kick Stage GSE					
Avionics					x
Handling and Transport	x	x			x
Propulsion and Mechanical	x	x			x
Kick Stage Facility					
Buildup and Checkout Area					x
Avionics Area					x
GSE Area					x
Airlock Station					x

5.2.3 Option 2, Clean Tug Processing, Spacecraft Mate in User Facility - Figure III-E-3 depicts the IUS, Tug, and kick stage flight hardware flow for this option. Upon return from mission the Tug is removed from the Orbiter and separated from the spacecraft in the OPF and moved to the TPF. Tug cleaning and complete stage refurbishment and postmaintenance checkout is completed in the TPF.

Upon completion of maintenance and checkout operations the Tug is ready for spacecraft and, if required, kick stage mate. If the Tug is scheduled for a DOD mission the mission-ready Tug is moved to the DOD facility for spacecraft mate, integrated system tests, and subsequent delivery to the pad. If the Tug is scheduled for a NASA or other non-DOD mission, the spacecraft and kick stage, if required, are moved into the TPF for mate to the Tug integrated systems test and transfer to the pad. If a non-DOD mission is scheduled to be flown on the IUS, a clean mission-ready IUS will be delivered to the TPF for spacecraft and kick stage, if required, mate, integrated systems testing, and transfer to the pad.

This approach would permit the procuring agency for each stage to process the stage for which they are responsible and not duplicate any effort, GSE or facilities. The Tug facility would require an IUS/spacecraft integration cell that would not contain all the checkout equipment of a refurbish/checkout cell. The IUS facility would require only a Tug/spacecraft integration cell and not all of the equipment associated with a Tug refurbish/checkout cell.

Upon arrival at the PCR/pad, the ground operations performed would be those that are characteristic of the particular stage and the associated spacecraft. All Tug secure operations can be delayed until after delivery of the mission-ready Tug to the DOD facility. Thus, security provisions must be provided at the DOD facility, PCR/pad, and OPF. Since the IUS will capture all of the currently planned DOD missions, all IUS secure operations will occur within the DOD facilities on DOD provided hardware, the exception being those secure operations required at the PCR/pad. Table III-E-6 provides a summary of facility and GSE requirements for this option.

5.2.4 Option 3, Clean Tug Processing, PCR Mate Option - Figure III-E-4 shows the IUS, Tug, and kick stage flight hardware flow for this option. Upon return from mission, the Tug is removed from the Orbiter and separated from the spacecraft in the OPF and the Tug moved to the TPF. The Tug undergoes cleaning and complete stage refurbishment and postmaintenance checkout in the TPF.

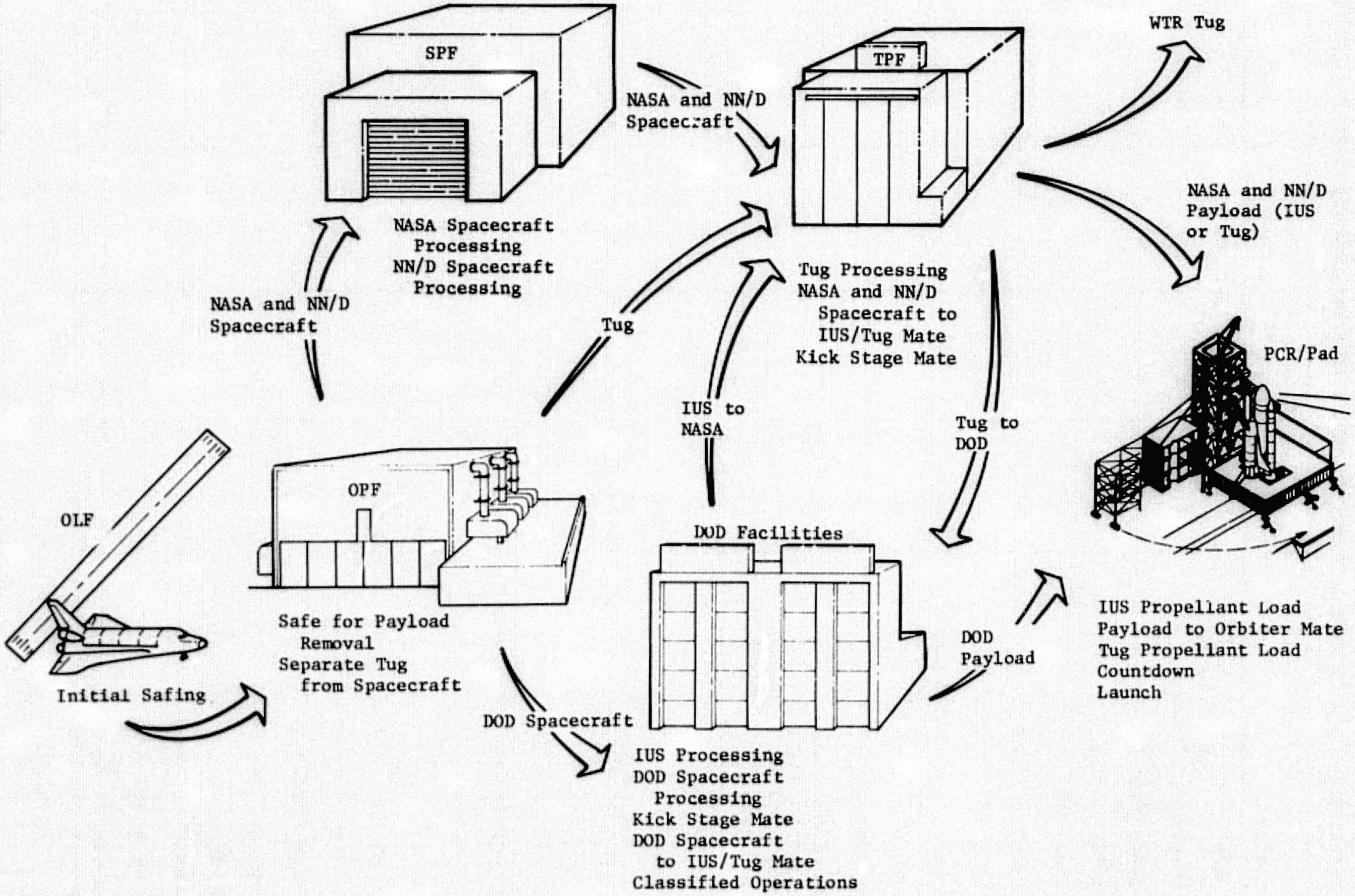


Figure III-E-3
Option 2, Clean Tug Processing, Spacecraft Mate in User Facility

Table III-E-6 Option 2 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF
Secure Area		x	x	x	
LPS Terminal	x	x	x	x	x
Clean Area (Bldg)	x	x	x		x
Airlock	x	x			x
Tug Unique GSE					
Avionics	x				
Handling and Transport	x	x		x	
Propulsion and Mechanical	x			x	
Structural	x				
Tug Facilities					
Engine Area	x				
Avionics Area	x				
H_2 Burn System	x	x		x	
O_2 Vent System	x			x	
GSE Area	x				
Airlock Station	x				
Checkout and Mate Cell	x	x			
APS Load System	x	x			
IUS-Spacecraft Mate Fixture	x				
Kick Stage GSE					
Avionics					x
Handling and Transport	x	x			x
Propulsion and Mechanical	x	x			x
Kick Stage Facility					
Buildup and Checkout Area					x
Avionics Area					x
GSE Area					x
Airlock Station					x
Tug-Spacecraft Mate Fixture		x			

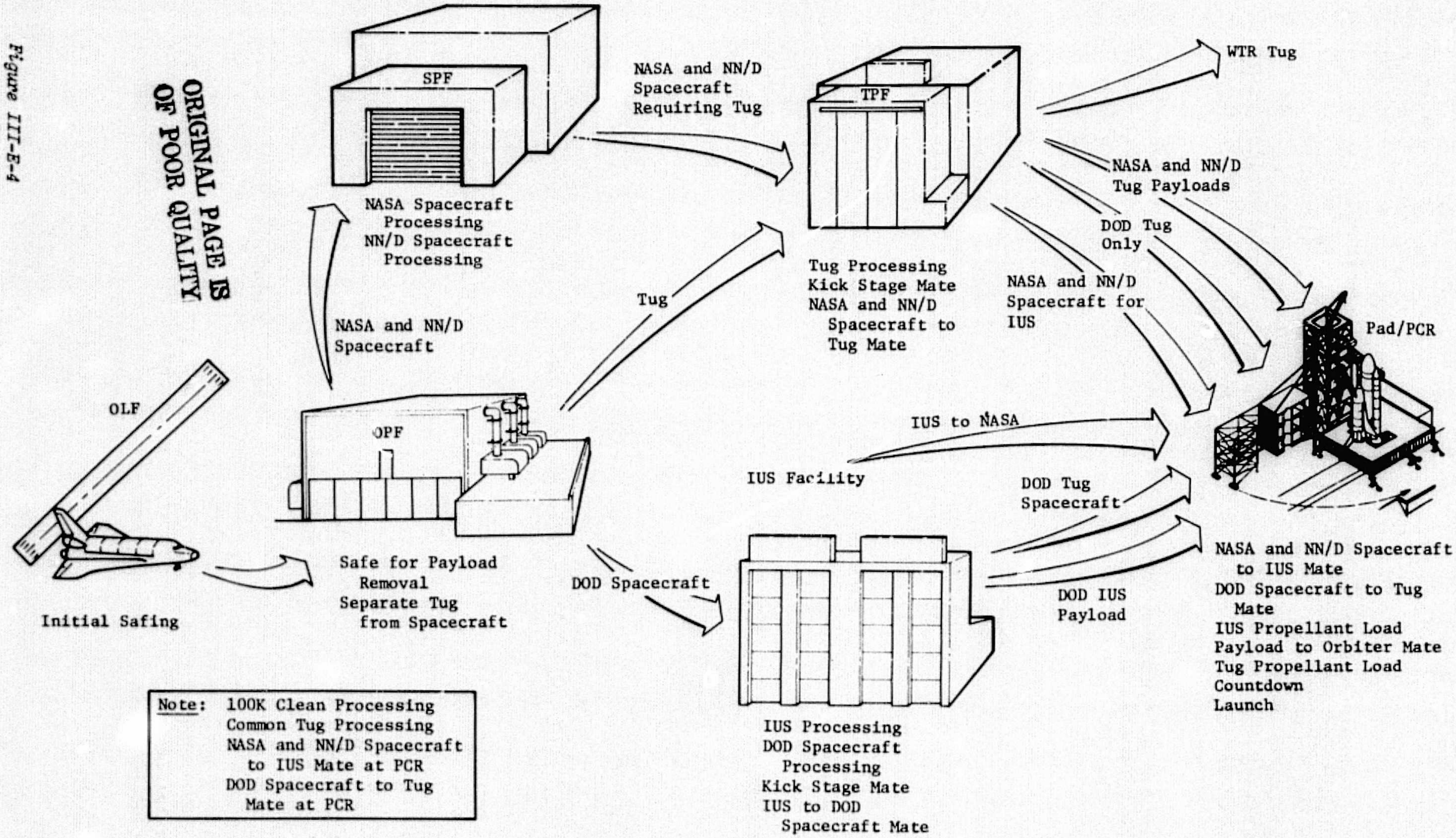


Figure III-E-4 Option 3, Clean Tug Processing, PCR Mate Option

Upon completion of maintenance and checkout operations, the Tug is ready for spacecraft and, if required, kick stage mate. If the Tug is scheduled for a NASA or NN/D mission, this mating and subsequent systems level verification will occur within the TPF. Similarly, in the case of an IUS scheduled for a DOD mission, the spacecraft/kick stage (if required) mating and subsequent integration verification will occur in the DOD facilities.

When a Tug is scheduled for a DOD mission, the mission-ready Tug, with kick stage, if required, is moved to the PCR for integration with the DOD spacecraft from their facilities, the mate and integration verification being accomplished in the PCR. Similarly, in the case of the IUS scheduled for a NASA or NN/D mission, the mission-ready IUS, with kick stage, if required, is mated to its assigned spacecraft in the PCR and subsequent integration systems verification performed. After the IUS/Tug integration activities are completed, whether off-pad or on-pad, the ground operations performed would be those that are characteristic of the particular stage and associated spacecraft.

This approach again permits the procuring agency to perform the processing operations on the stage for which it is responsible It limits secure operations to three areas that can be readily designed and operated as secure areas, the DOD facilities, PCR/pad and the OPF. The TPF would contain no provisions for security or any IUS operations; the DOD facilities would not have the capability of any Tug operations. Table III-E-7 provides a summary of facility and GSE requirements for this Option.

5.2.5 Option 4, Uncleaned Tug Processing, Spacecraft Mate in Separate Integration Facility - Figure III-E-5 depicts the IUS, Tug, and kick stage flight hardware flow for this option. Upon return from the mission, the Tug is removed from the Orbiter and separated from the spacecraft in the OPF. The Tug is then moved to the TPF for processing. Tug processing would be accomplished on the Tug in the as-returned condition, i.e., no stage cleaning before refurbish, in a factory clean area that would ensure that the Tug would not become further contaminated because of the checkout area environment.

If the Tug is scheduled for NASA or NN/D mission, upon completion of Tug refurbish and checkout, it is moved to a payload mate facility where it is cleaned as required, then mated to the spacecraft. An IUS scheduled for a NASA or NN/D mission also comes to this payload mate facility in a mission-ready condition from the DOD facilities. After IUS/Tug, spacecraft and kick stage, as required, mate and integration verification, the payload is moved to the launch pad. The DOD spacecraft are mated to the IUS in the DOD facility and to the Tug in the PMF. The PCR/pad operations performed after delivery to the pad area are those characteristic of the particular stage and spacecraft.

Table III-E-7 Option 3 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF
Secure Area			x	x	
LPS Terminal	x		x	x	x
Clean Area (Bldg)	x		x		
Airlock	x				
Tug Unique GSE					
Avionics	x				
Handling and Transport	x			x	
Propulsion and Mechanical	x			x	
Structural	x				
Tug Facilities					
Engine Area	x				
Avionics Area	x				
H_2 Burn System	x			x	
O_2 Vent System	x			x	
GSE Area	x				
Airlock Station	x				
Checkout and Mate Cell	x				
APS Load System	x				
Kick Stage GSE					
Avionics					x
Handling and Transport	x	x			x
Propulsion and Mechanical	x	x			x
Kick Stage Facility					
Buildup and Checkout Area					x
Avionics Area					x
GSE Area					x
Airlock Station					x

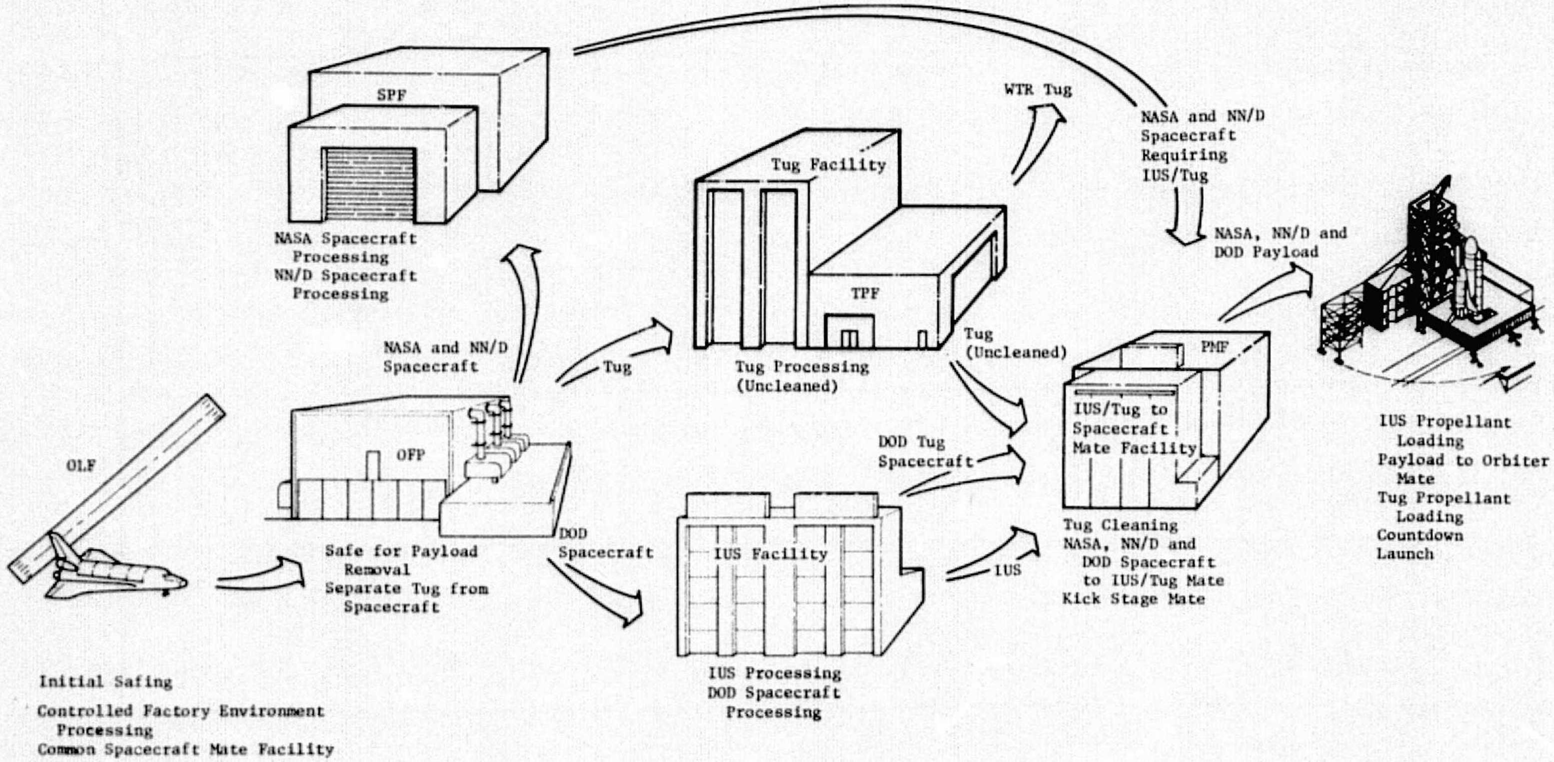


Figure III-E-5
Option 4, Uncleaned Tug Processing, Spacecraft Mate in Separate Integration Facility

This approach permits the procuring agency for each stage to process the stage for which they are responsible with no duplication of effort or equipment. The PMF would contain IUS/Tug to spacecraft mating/integration cells only, and the minimum GSE for integration testing. Since the kick stages will be used only by NASA and NN/D Tug and IUS flights, all kick stages would be integrated into the payload in the PMF.

This approach does require a secure area in the PMF for DOD Tug flights. The DOD IUS mission spacecraft would be mated and verified entirely within the DOD facility complex before movement to the PCR/pad. Table III-E-8 provides a summary of facility and GSE requirements for this option.

5.2.6 Option 5, Uncleaned Tug Processing, Single Security Area for DOD Payloads - Figure III-E-6 depicts the IUS, Tug, and kick stage flight hardware flow for this option. Upon return from a mission, the Tug is removed from the Orbiter and separated from the spacecraft in the OPF. The Tug is then moved to the TPF for refurbish and checkout. The Tug refurbish/checkout activities are conducted in a factory clean environment that would not degrade the cleanliness condition of the as-returned Tug.

Upon completion of Tug refurbishment/checkout, a portable or temporary clean room is installed around the Tug and the Tug is cleaned to be compatible with the Orbiter bay. If the Tug is assigned to a DOD mission, the clean mission-ready Tug is then moved to the DOD facilities for spacecraft mate and integrated testing. If the mission assignment is a NASA or NN/D spacecraft, this spacecraft and any kick stages required would be moved to the TPF for mate with the Tug. If the mission assignment is for an IUS, the clean mission ready IUS will be moved to the TPF from the DOD facilities, placed in a temporary clean room, and mated with the spacecraft and kick stages, as required. After mate and integration verification, the NASA or NN/D payload is moved to the PCR/pad for Shuttle integration. All DOD spacecraft will be integrated to both IUS and Tug in the DOD facilities and then moved to the PCR/pad for Shuttle integration and prelaunch operations.

This approach permits the responsible agency for each stage to perform the processing for that stage. The TPF would contain an IUS to spacecraft mate cell and the DOD facilities would have a Tug to spacecraft mate cell, both with the minimum support equipment for spacecraft integration and verification. Kick stages would be integrated both in the TPF, for NASA and NN/D flights, and in the DOD facility, for DOD missions. This approach requires a security provision in the DOD facilities and PCR/pad for prelaunch, and at the OPF for postlaunch activities. Table III-E-9 provides a summary of facility and GSE requirements for this option.

Table III-E-8 Option 4 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF	PMF
Secure Area		x	x	x		x
LPS Terminal	x	x	x	x	x	x
Clean Area (Bldg)			x			x
Airlock						x
Tug Unique GSE						
Avionics	x					
Handling and Transport	x			x		x
Propulsion and Mechanical	x			x		
Structural	x					
Tug Facilities						
Engine Area	x					
Avionics Area	x					
H_2 Burn System	x			x		
O_2 Vent System	x			x		
GSE Area	x					
APS Load System						x
Tug Airlock Station						x
IUS Airlock Station						x
Tug-Spacecraft Mate Fixture						x
IUS-Spacecraft Mate Fixture						x
Kick Stage GSE						
Avionics					x	
Handling and Transport					x	x
Propulsion and Mechanical					x	x
Kick Stage Facility						
Buildup and Checkout Area					x	
Avionics Area					x	
GSE Area					x	

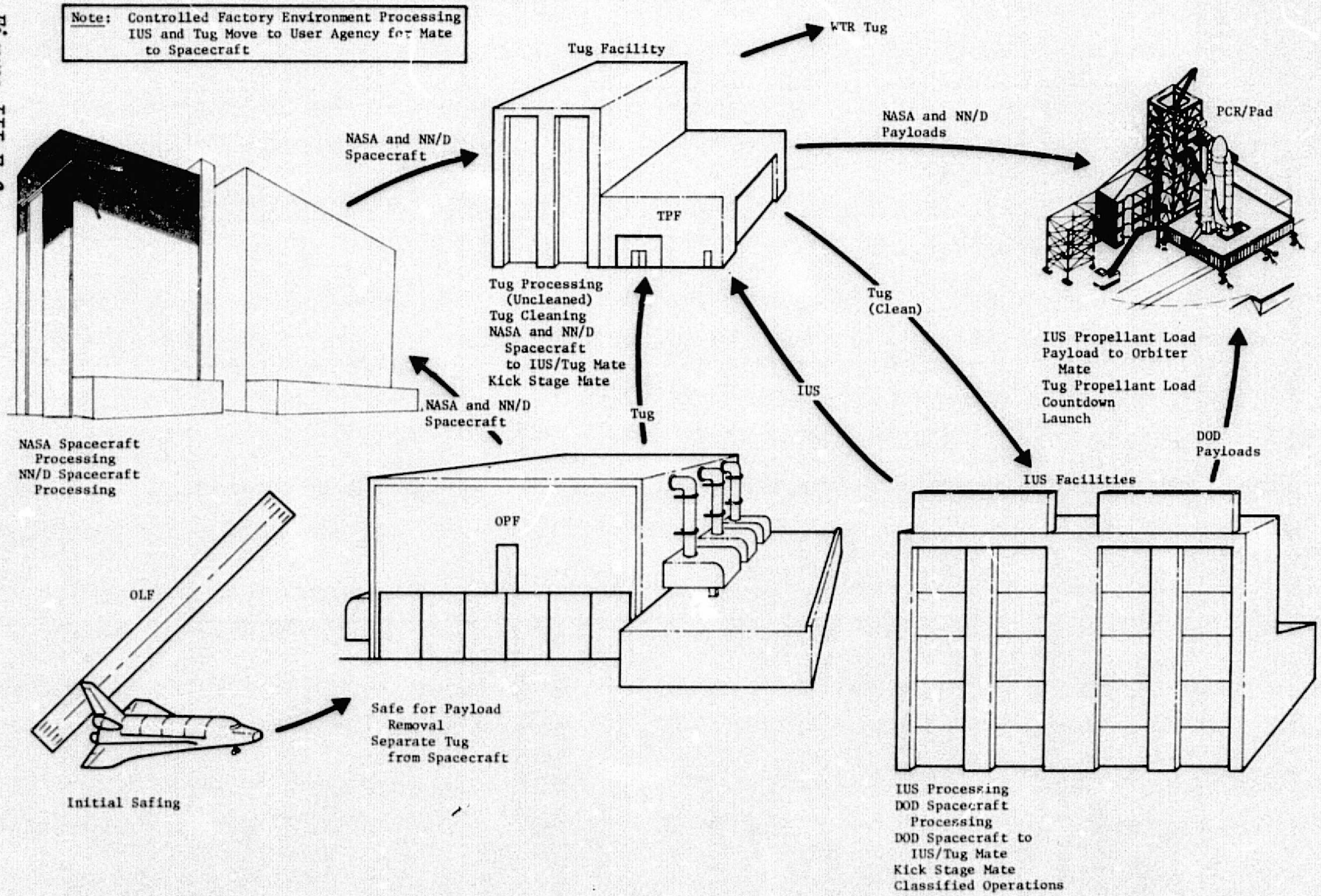


Figure III-E-6
Option 5, Uncleaned Tug Processing, Single Security Area for DOD Payloads

Figure III-E-6

Table III-E-9 Option 5 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF
Secure Area		x	x	x	
LPS Terminal	x	x	x	x	x
Clean Area (Bldg)		x	x		
Airlock (portable)	x				
Tug Unique GSE					
Avionics	x				
Handling and Transport	x	x		x	
Propulsion and Mechanical	x				
Structural	x				
Tug Facilities					
Engine Area	x				
Avionics Area	x				
H_2 Burn System	x			x	
O_2 Vent System	x			x	
GSE Area	x				
APS Load System	x				
Tug-Spacecraft Mate Fixture	x	x			
IUS-Spacecraft Mate Fixture	x				
Kick Stage GSE					
Avionics					x
Handling and Transport	x	x			x
Propulsion and Mechanical	x	x			x
Kick Stage Facility					
Buildup and Checkout Area					x
Avionics Area					x
GSE Area					x

5.2.7 Option 6, Uncleaned Tug Processing in Joint IUS/Tug Facility - Figure III-E-7 depicts the IUS, Tug and kick stage flight hardware flow for this option. Upon return from a mission, the Tug is removed from the Orbiter and is separated from the spacecraft in the OPF. The Tug is moved to the TPF where it undergoes refurbishment and checkout in the as-received condition in a factory clean area. For IUS missions, a new IUS from the manufacturer or storage will be moved to the TPF for checkout. Cleanliness will be limited to an environment that does not contribute to further contamination of a returned vehicle.

Upon completion of refurbishment and postmaintenance checkout, the IUS/Tug is cleaned in a portable or temporary clean room. The spacecraft (DOD, NASA, and NN/D) and any kick stages required, are moved to the TPF and mated to the IUS/Tug. Integrated testing is then performed, and the payload is moved to the PCR/pad for Shuttle mate and prelaunch operations.

In this approach, all IUS and Tug processing is done in a facility jointly occupied by NASA and DOD. Secure areas/cells will be required for DOD operations in the TPF. The PCR/pad and OPF will require the same security provisions as on other options. Table III-E-10 is a summary of facility and GSE requirements for this option.

5.2.8 Option 7, Uncleaned Tug Processing, Separate IUS and Tug Facilities - Figure III-E-8 depicts the IUS, Tug and kick stage flight hardware flow for this option. Upon return from a mission, the Tug is removed from the Orbiter and separated from the spacecraft in the OPF. The Tug is moved to the TPF for refurbish and checkout. These activities are conducted in a factory clean environment that would not degrade the cleanliness of the as-returned Tug.

Upon completion of Tug refurbishment/checkout, a portable or temporary clean room is installed around the Tug and it is cleaned to be compatible with the Orbiter bay. All spacecraft (DOD, NASA and NN/D) assigned to be flown on a Tug will be integrated in the TPF. All spacecraft assigned to be flown on an IUS will be integrated in the DOD IUS facility. In each case, after mate and integration verification, the payload is moved to the PCR/pad for integration with the Shuttle, prelaunch and launch activities.

This approach enables the stage processing to be accomplished by the procuring agency. Spacecraft integration would be accomplished in each case by the using agency. It eliminates the requirements for duplicate sets of stage GSE in the processing facilities. Security will be required in the TPF as well as the DOD facilities, PCR/pad, and OPF. A summary of facility and GSE requirements for this option is shown in Table III-E-11.

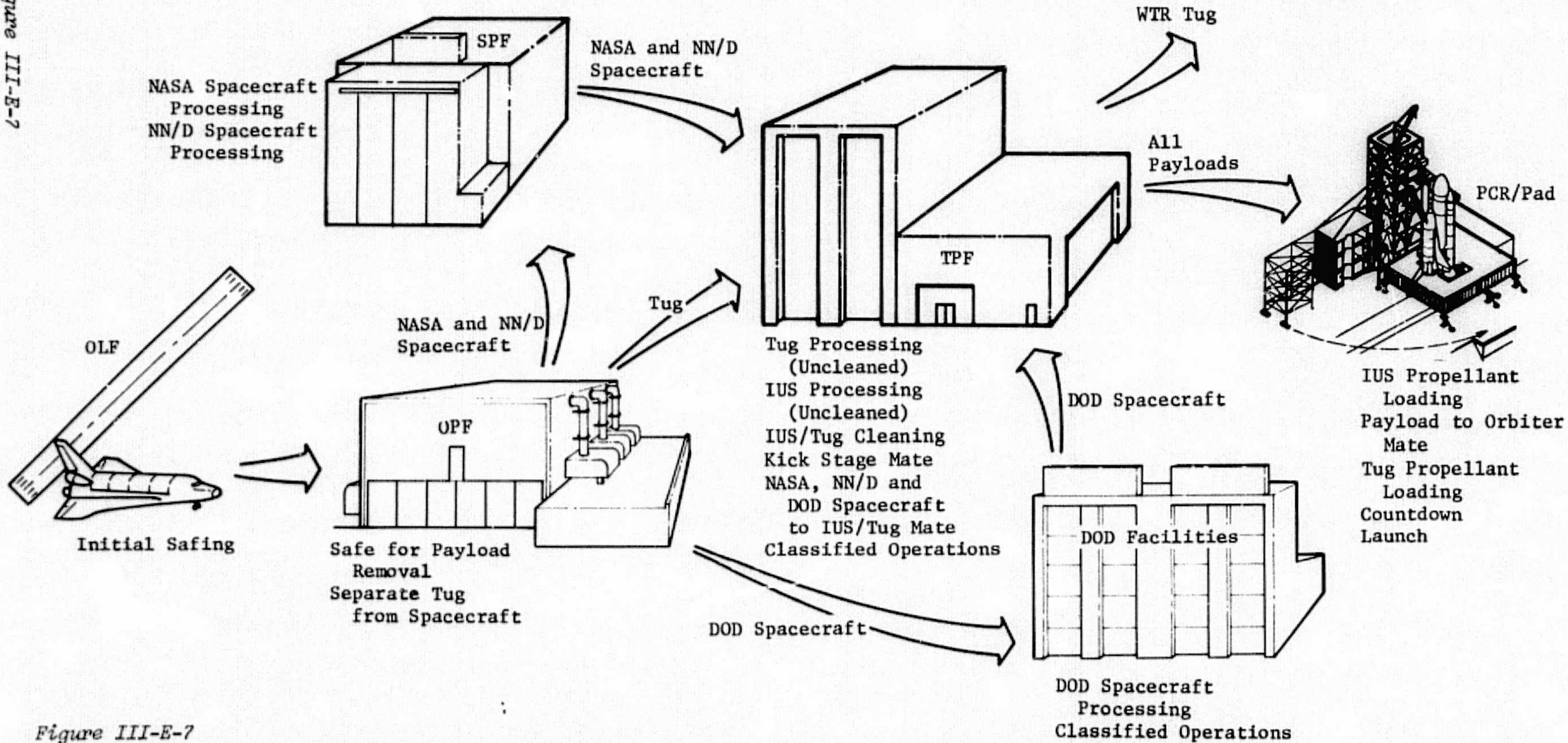
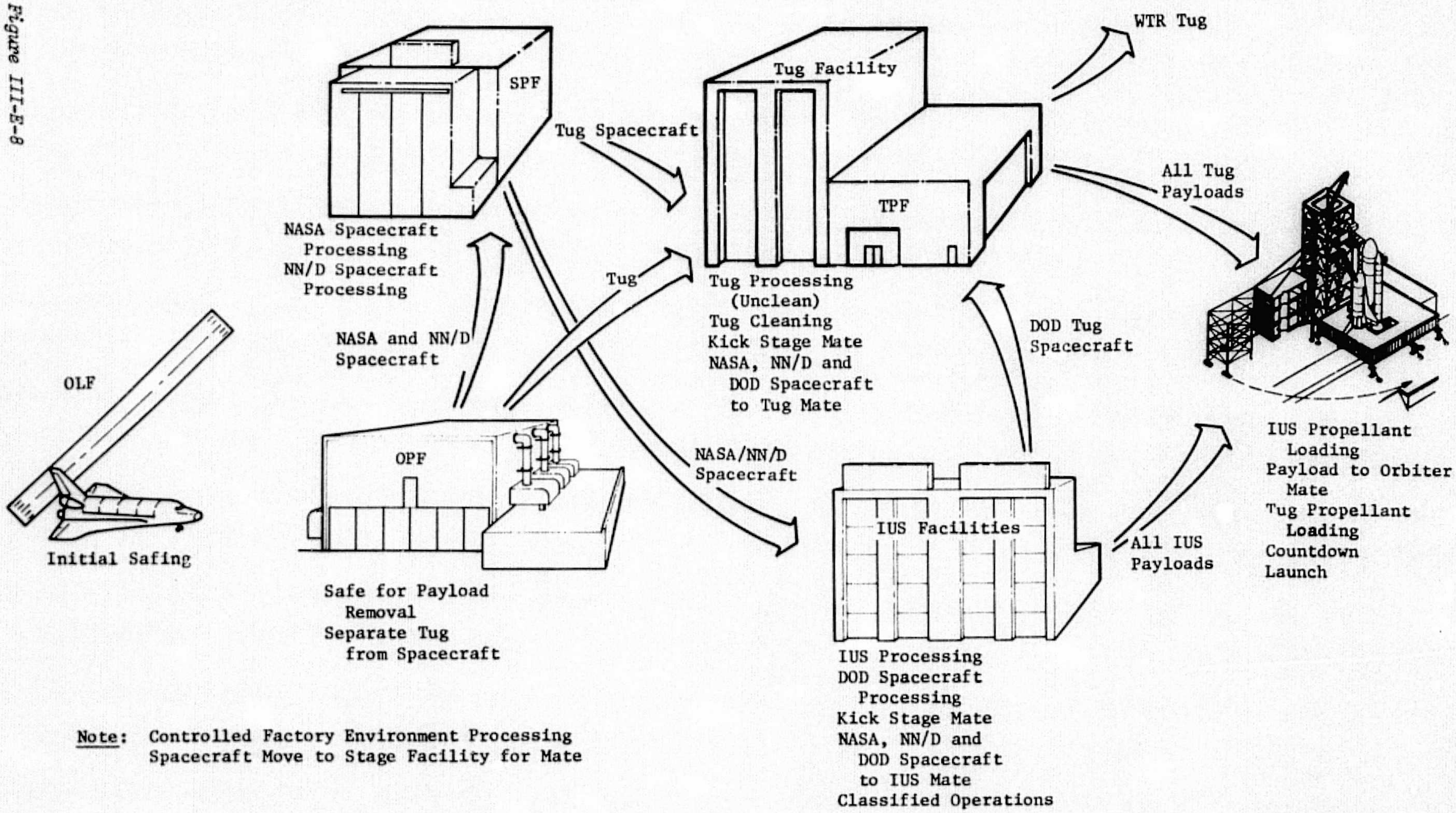


Figure III-E-7
Option 6, Uncleaned Tug Processing in Joint IUS/Tug Processing Facility

Table III-E-10 Option 6 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF
Secure Area	x	x		x	x
LPS Terminal	x		x	x	x
Clean Area (Bldg)			x		
Airlock					
Tug Unique GSE					
Avionics	x				
Handling and Support	x			x	
Propulsion and Mechanical	x				
Structural	x				
Tug Facilities					
Engine Area	x				
Avionics Area	x				
H_2 Burn System	x			x	
O_2 Vent System	x			x	
GSE Area	x				
APS Load System	x				
Portable Clean Room	x				
Kick Stage GSE					
Avionics					x
Handling and Transport	x				x
Propulsion and Mechanical	x				x
Kick Stage Facility					
Buildup and Checkout Area					x
Avionics Area					x
GSE Area					x



Note: Controlled Factory Environment Processing
Spacecraft Move to Stage Facility for Mate

Figure III-E-8 Option 7, Uncleaned Tug Processing, Separate IUS and Tug Processing Facilities

Table III-E-11 Option 7 Facility and GSE Requirements Summary

Consideration	TPF	DOD	Pad/ PCR	OPF	KPF
Secure Area	x	x	x	x	
LPS Terminal	x		x	x	x
Clean Area (Bldg)			x		
Airlock					
Tug Unique GSE					
Avionics	x				
Handling and Support	x			x	
Propulsion and Mechanical	x			x	
Structural	x				
Tug Facilities					
Engine Area	x				
Avionics Area	x				
H_2 Burn System	x			x	
O_2 Vent System	x			x	
GSE Area	x				
APS Load System	x				
Portable Clean Room	x				
Kick Stage GSE					
Avionics					x
Handling and Transport	x	x			x
Propulsion and Mechanical	x	x			x
Kick Stage Facility					x
Buildup and Checkout Area					x
Avionics Area					x
GSE Area					x

5.2.9 Assessment - To objectively evaluate the relative merits of those seven options, the following items, or criteria, were considered:

1) Safety - Personnel and systems safety affect evaluation of each option;

2) Cost - Facility and GSE costs for each option;

3) Flexibility - Operational flexibility to permit workarounds and accommodate contingencies;

4) Timeline - Time required to complete Tug turnaround operations;

5) Security - Ease of maintaining secure operations for all DOD missions;

6) Logistics - Hardware spares, vehicle handling, and crew training requirements;

7) Building Availability - Compatibility of operational requirement with current building usage schedules and effective use of facility capability.

Numerical values have been assigned to each of these criteria. The best approach, or most desirable being rated a "one", and the least desirable being rated a higher number based on the number of options in the category. Thus, the option with the lowest numerical score becomes the best option in that category based on the criteria used. The two categories considered were clean processing and uncleaned processing. Table III-E-12 displays the results of this analysis.

Table III-E-12 Option Assessment Summary

	Options						
	Clean Processing			Uncleaned Processing			
Criteria	1	2	3	4	5	6	7
Safety	2	1	3	4	2	3	1
Cost	3	1	2	4	3	1	2
Flexibility	2	3	1	4	3	1	2
Timelines	1	1	1	4	1	1	1
Security	1	2	3	2	1	3	3
Logistics	3	1	1	4	3	1	2
Building Availability	1	1	1	2	1	1	1
Total	13	10	12	24	14	11	12
Rating	3	1	2	4	3	1	2

Of the three clean Tug processing options, this assessment summary shows that Option 2 is the best, and of the four uncleaned Tug processing options, Option 6 is the best approach. Because the results of the Tug Processing in an Unclean Environment Analysis, Addendum 6, has resulted in the recommendation to process the Tug unclean, Option 6 becomes the recommended option.

The following sections provide a summary of the tradeoffs for each of the criteria considered.

5.2.9.1 Safety - An analysis of the transition phase ground operations approach options was made to establish safety evaluation criteria. The purpose of the analysis was to establish criteria to identify variables between options having an impact on personnel and system safety. Some functions that are normally considered t be hazardous operations, such as APS servicing, were excluded because they are common to all options. The resulting criteria, listed below, was then applied to each option to develop the safety ratings shown in Table III-E-13.

1) Transportation and Handling - Each vehicle movement presents the potential for accidents/incidents. Therefore, the number of moves between facilities may be used as a variable rating factor. The options include moving IUS, Tug, and spacecraft to meet mixed agency requirements. The total payload element movements are considered.

2) Personnel Considerations - The following two elements were derived:

    a) Error Probability - Hazardous conditions are frequently created as a result of human error. The predition of human error probability is very difficult, but, in general, the probability increases with the complexity of operations. Mixing of payload element operations within a facility is an example of increased complexity and was used as a relative rating factor.

    b) Safety and Health - The well-being of operations personnel is affected by the operating environment. Conditions such as tank access, congestion, and hazardous materials are detrimental to personnel safety and health. Contingency situations requiring egress or escape routes from an extremely hazardous area are also considered in this category. Relative ratings for each option were developed for these considerations.

Table III-E-13 Safety Considerations

Criteria	Options: Clean Processing 1	2	3	Uncleaned Processing 4	5	6	7
Transportation and Handling							
IUS Movement							
With DOD Spacecraft	2	2	2	2	2	2	2
With NASA and NN/D Spacecraft	2	3	2	3	3	2	2
Tug Movement							
With DOD Spacecraft	2	3	2	3	3	2	2
With NASA and NN/D Spacecraft	2	2	2	3	2	2	2
Spacecraft Movement before Mate with IUS/Tug							
DOD for IUS	1	1	1	1	1	2	1
DOD for Tug	1	1	2	2	1	2	2
NASA, NN/D for IUS	2	2	3	2	2	2	2
NASA, NN/D for Tug	2	2	2	2	2	2	2
Total Moves	14	16	16	18	16	16	15
Transport Rating	1	3	3	4	2	2	1
Personnel Considerations							
Error Probability Rating	3	1	2	4	3	2	1
Safety and Health Rating	2	1	3	2	2	4	1
Sum of Ratings	6	5	8	10	7	8	3
Overall Rating	2	1	3	4	2	3	1

5.2.9.2 *Cost Analysis* - A cost analysis was performed on the seven options for the DDT&E phase. Considerations were quantities of avionics GSE, handling and transportation GSE, propulsion and mechanical GSE and structural GSE for the Tug, IUS and the kick stage. Modification costs of the applicable facilities for each option were also considered; items such as SAEF-1, OPF, VAB, warehousing, LPS terminals, secure areas, and launch pad modifications were included.

Each identifiable Tug unique GSE item was individually priced. Kick stage GSE was factored from the Tug-unique GSE values, and IUS GSE costs were only those items to be built to support the new facility. All existing IUS GSE was defined as available to support the IUS.

Facility modification of the SAEF-1 considered raising the airlock roof, modifying the inward outer doors, extending the air conditioning ducts, installing test cells, wall and emergency exits, work platforms, relocating electrical power and piping, installing hydrogen burn stacks and oxygen vents.

Facility modification of the VAB considered installation of class 100,000 clean area in the spacecraft mate area of the refurbish/checkout cells, and hydrogen burn stack and oxygen vent installation.

Other facility modifications were considered that did not alter any options such as building a warehouse with access roads and paving. Launch pad modifications and OPF modifications including crane installation, electrical power, GN_2 and He lines and shop and office space.

Results of the study reveal that Option 2 is the preferred option for clean processing, while Option 6 is the preferred option for unclean processing. These results are summarized in Table III-E-14. Note that there are no costs involved for IUS-unique GSE for Options 6 and 7. In Option 6, IUS processing has been performed in VAB and no additional equipment is needed; in Option 7, all IUS activity is conducted in existing DOD facilities.

Table III-E-14 Cost Considerations, $ In Millions

	Options						
	Clean Processing			Unclean Pro essing			
	1	2	3	4	5	6	7
Tug-Unique GSE	13.53	8.62	8.62	8.35	8.10	7.49	7.49
Tug Facility Modification	6.10	5.96	5.92	11.69	6.18	5.91	6.09
IUS-Unique GSE	0.20	0.20	0.20	0.20	0.20	-----	-----
IUS Facility Modification	0.30	0.27	0.27	0.33	0.45	0.06	0.06
Kick Stage GSE	3.06	2.80	2.80	2.79	2.80	2.80	2.80
Launch Pad/PCR, OPF and Warehouse	0.57	0.57	0.64	0.57	0.57	0.57	0.57
Total, $ M	23.76	18.42	18.45	23.93	18.30	16.83	17.01
Rating	3	1	2	4	3	1	2

5.2.9.3 *Operations Flexibility* - The criteria, on which the operations flexibility evaluation for each option is based, follows.

1) Adaptation to contingencies - degree to which an option can facilitate major contingencies or rescheduling in the IUS/Tug operations flow. These contingencies could be schedules, delayed spacecraft, Tug system failure, etc.

2) Consolidation of Tug operations - degree on which complete IUS/Tug operation can be completed in one area or test cell.

3) Movement between processing facilities - the preparations to move, movement, and subsequent handling to prepare for follow-up operations require time, and subject the stage to possible damage. A reduction in these activities is desired providing it does not provide a similar problem for spacecraft.

4) Crew availability/movement - any movement of an operations crew from its normal work area to another work area under different conditions, i.e., clean areas, agency jurisdictions, security requirements, etc, can have an efficiency impact on the crew. Minimum crew movement is desirable for IUS/Tug operations.

5) Hardware availability/movement - any movement of an IUS/Tug and/or crew will require the movement of supporting GSE and tools. Again, as with 3) and 4), this is undesirable and should be worked around whenever possible.

6) Logistics Supply - the degree to which the logistics supply operations for hardware, software, and procedures is complicated by the option.

A rating of from one through three for clean processing, and from one through four for unclean processing, was used and a value assigned to each criterion by option. The lowest number total rating is the best option. Table III-E-15 shows the results of the flexibility evaluation for each option.

Table III-E-15 Operations Flexibility Comparison

Criteria	Options						
	Clean Processing			Uncleaned Processing			
	1	2	3	4	5	6	7
Adaptation to Contingencies	1	2	3	5	3	1	2
Consolidation of Tug Operations	1	3	2	4	3	1	2
Movement between Processing Facilities	2	3	1	4	3	1	2
Crew Availability/Movement	2	3	1	4	3	1	2
Hardware Availability/Movement	2	3	1	4	3	1	2
Logistics Supply	2	3	1	4	3	1	2
Total	10	17	9	25	18	6	12
Rating	2	3	1	4	3	1	2

5.2.9.4 *Timeline Comparison* - The green light Tug ground operations resource requirements were reviewed for each option and the span hours to complete each option determined. The results are shown in Table III-E-16. Timeline effects by each option were minimal, the timeline variations were caused by deletion of Tug handling movements within and between the various facilities.

Table III-E-16 Timeline Comparison by Hours

Criteria	Options						
	Clean Processing			Uncleaned Processing			
	1	2	3	4	5	6	7
Postflight Safing	27	27	27	27	27	27	27
Scheduled and Unscheduled Maintenance and Refurbish	44	44	44	34	34	34	34
Postmaintenance Checkout	25	25	25	25	25	25	25
IUS/Tug - Spacecraft Mating and Checkout	16	16	16	25	22	22	22
Payload - Shuttle Mating and Checkout	33	33	33	33	33	33	33
Prelaunch Checkout and Countdown	12	12	12	12	12	12	12
Total	157	157	157	156	153	153	153
Rating	1	1	1	4	1	1	1

5.2.9.5 *Security* - The criteria selected for the assessment of the security aspects of each option are:

1) Number of secure areas required - the number of checkout/integration areas, cells, or buildings vary with the options. The fewer areas required are more optimum because of initial and recurring costs and ease of overall operations.

2) Ease of access control - the ease of which a cell, area, or level of a cell, or building can be controlled. The easier an area can be controlled, the better the rating. Access control includes phylical access, acoustics access, communications access, power access, etc.

3) Software handling - ease of handling secure software with the hardware flow described in the various options.

4) Number of secure movements - the number of extra-facility movements of DOD spacecraft or payloads for both IUS and Tug assignments.

A summary of the results of this assessment is shown in Table III-E-17. The lowest value assigned to the criterion indicates the better approach.

Table III-E-17 Security Considerations

Criteria	Options						
	Clean Processing			Uncleaned Processing			
	1	2	3	4	5	6	7
Number Secure Areas Required	2	2	2	3	2	3	3
Ease of Access Control	1	2	3	2	1	4	3
Software Handling	1	1	1	1	1	1	1
Number of Secure Movements	1	1	1	3	1	2	3
Total	5	6	7	9	5	10	10
Rating	1	2	3	2	1	3	3

5.2.9.6 *Logistics* - Logistics criteria were applied to each of the seven transition phase options. Facility in operations, duplication of tasks, added training or documentation requirements, spares inventory and control, etc, were examined for impact based on such factors as number of moves and the handling requirements inherent in them, the number of checkout or handling crews required, the amount of spares required at different processing locations, and the ease of warehousing, inventory, and spares issuance.

The number of total moves and necessary handling operations did not differ significantly for the various operations running from a low of 14 fcr Option 1 to a high or 18 for Option 4. Although increases in handling time are obvious for the options with high numbe. of moves, no handling GSE was identified as unique to one option or another. The duplication of handling GSE required for Option 1 and the probability of shared use of GSE under Option 6 were the two extremes noted in this area.

Facility of maintenance scored even for all options except Option 1 and Option 6. Option 1 scored high because of the obvious duplication of maintenance activities at both the DOD and NASA processing facilities. Option 6 scored high because of IUS and Tug maintenance activities taking place concurrently in the same facility.

Again, the duplication of activities under Option 1 gave it the highest score as far as spares considerations are concerned. Under this option, critical IUS and Tug spares would have to be made available at both DOD and NASA facilities with added requirements for inventory management. The optimum situation for spares management was considered to fall under Option 6, which would permit central warehousing and control for the bulk of both IUS and Tug spares at the VAB.

Training and operations maintenance documentation considerations are worst-case under Option 1, which requires duplicate crews for IUS and Tug or at least duplicate equipment and facility interface training for a common crew to operate in both processing facilities. Other options rank close to one another with the exception of Option 4 which introduces additional requirements for a payload mate facility, and Option 6 which could result in a reduction of training requirements based on reduced number of crews for Tug and IUS operations in one processing facility.

Table III-E-18 is a summary of the evaluation of these logistics considerations by option.

Table III-E-18 Logistics Considerations

	Options						
	Clean Processing			Uncleaned Processing			
Criteria	1	2	3	4	5	6	7
Inter-Facility Moves and Handling Operations	1	3	3	5	3	3	2
Handling GSE Maintenance and Repair	5	3	3	4	3	1	3
Facility of Maintenance Tasks	3	2	2	2	2	3	2
Duplication of Maintenance Tasks	5	3	3	3	3	3	3
Critical Spares Required at Processing Facility	5	3	3	2	2	2	2
Spares Warehousing, Inventory Control, and Dispatch	4	3	3	2	2	1	2
Flexibility in Providing Storage	4	3	3	2	2	3	2
Training as a Function of Crew Size and Number of Crews	5	3	3	4	3	2	3
Operations Maintenance Documentation as a Function of Volume and Change Traffic	4	3	3	3	3	3	3
Total	36	26	26	27	23	21	22
Rating	3	1	1	4	3	1	2

5.2.9.7 *Building Availability* - The demand for KSC facilities during the Shuttle era is a critical factor in the selection of IUS and Tug checkout and refurbish facilities. Overall Shuttle program requirements must be considered to determine the most effective use of existing KSC facilities and their capabilities, i.e., clean rooms/buildings, hazardous operations compatibility, etc. A survey of the existing KSC facilities has resulted in a selection of two buildings that are adaptable for Tug operations: (1) SAEF-1 for clean IUS/Tug processing, and (2) VAB low bay for uncleaned IUS/Tug processing. Tug Site Activation subplan D provides a top level activation plan for both the SAEF-1 and the VAB low bay.

The SAEF-1 would be an adequate facility, when modified as described in subplan D, for clean IUS/Tug operations. However, if this facility is used for IUS operations, expendable or reusable, in the 1980 to 1984 time period, it could not be modified for Tug operations because of space requirements and IUS operations interference during the Tug activation phase. Therefore, it is assumed that the IUS checkout and/or refurbish checkout area is not located in the SAEF-1 and that the building would be available for modification no later than January 1980.

Because all three Tug clean processing options (1, 2, and 3) use the SAEF-1, all are rated equal as far as building availability. Each approach requires that the facility be available for modification at the same time, differences in building and GSE costs by option are included in the cost criterion.

The VAB low bay would be an adequate facility, when modified as shown in subplan D, for uncleaned Tug operations. This facility would be of sufficient size to process the IUS on one side of the transfer aisle and the Tug on the other or both on one side. This approach would permit site activation for the Tug to commence upon completion of site activation/validation for the IUS. In this case, the Tug activation activities would not interfere with or compromise IUS processing operations. Inasmuch as the recommendation of the Space Tug Processing in an Unclean Environment Analysis is to process unclean, and IUS/Tug processing in the low bay would permit the use of SAEF-1 and its overall cleanliness capability to be used by the various spacecraft, the VAB low bay appears to be the optimum facility usage in view of the overall Shuttle program requirements. The use of additional buildings for spacecraft mating, other than in an SPF, would affect the total facility shortage problem. Therefore, the option requiring a payload mate facility (Option 4) has been deemed to be the least desirable approach, while the other unclean processing options are rated equal as far as building availability is concerned.

6.0 Conclusions

The conclusions reached and recommendations arrived at in developing this subplan are summarized as follows:

1) There is little hardware commonality between the IUS and Tug.

2) There is little apparent advantage to a common IUS/Tug processing facility.

3) Do not "force fit" IUS into the Tug Processing Facility.

4) If the Tug is to be processed in a class 100,000 clean environment, the SAEF-1 should be used as the TPF.

5) If the Tug is processed in the SAEF-1, the IUS processing should be done in a separate facility.

6) If the Tug is to be processed uncleaned in a factory clean environment (recommended), the VAB low bay should be used as the TPF.

7) If the Tug is processed in the VAB, IUS processing could also be accomplished there.

8) Plan and provide common (IUS/Tug) facilities for kick stage checkout, OPF demate, PCR operations office space, shop and maintenance areas.

9) Plan and provide common GSE for APS servicing, helium pressurization, PCR access platforms, and site-to-site transportation equipment.

10) The IUS, Tug, and Orbiter schedules must be integrated during the transition period to provide for impact of pad activation, Tug engineering model checkout and first flight article checkout and launch during the peak IUS traffic year.

11) Transition from IUS to Tug is expensive from the standpoint of using and maintaining two stages in operation at the same time. The transition period should be kept to a minimum. Residual IUSs can be used for several missions that normally do not require the energy capabilities of the Tug.

CONTENTS

Figure

Table

1.0 Introduction

This subplan identifies potential design impacts to the Tug/Shuttle and Spacecraft Systems that are related to ground operations. Generally, the subplan provides an assessment of the results of Tasks 1.0 through 6.0 of the Tug Fleet and Ground Operations Schedules and Control Study to determine design factors that have an impact on the Tug Acquisition Phase. From these assessments we have developed Tug design and development recommendations that will minimize operational impacts on the areas of facilities, GSE, transportation, maintenance, test and checkout, software and logistics.

The results of Tasks 1.0 through 6.0 and their associated requirements, options, and recommendations have been interleaved with the twelve primary study elements defined in the contract, and have been evaluated for design and development impacts. These assessments are documented in paragrah 3.0 of this subplan. Factors that could not be interleaved with the primary study elements or required further study are contained in paragraph 4.0 and Tug design and development recommendations are contained in paragraph 5.0 of this subplan.

2.0 General Requirements

The following ground rules were developed to establish a baseline from which to assess study results generated in Tasks 1.0 through 6.0 of the Tug Fleet and Ground Operations Schedules and Control Study:

1) The spacecraft is flight ready when it is received for Tug/spacecraft integration.

2) No maintenance of the Tug will be performed while the Tug is in the Orbiter payload bay.

3) Tug operations will be performed at both ETR and WTR. All Tug processing will be accomplished at ETR. Tugs scheduled to be launched at WTR will be shipped to WTR in a near-launch-ready condition.

4) DOD and NASA Tugs will be essentially identical and considered interchangeable.

5) NASA will develop and provide the Tug and kick stages.

6) NASA and DOD payloads may be flown on either IUS or Tug depending on vehicle availability and mission capability.

7) Component Changeout during Tug processing shall be limited to LRUs.

8) The LPS capability will be available to Tug/payload up to T-0 in the countdown to provide total system checkout.

9) Tug cryogenic propellant loading is accomplished remotely with the Tug in the Orbiter payload bay and with the payload bay doors closed.

10) Tug transportation between ETR and WTR will be by air.

11) While Tug/spacecraft are in the Orbiter payload bay, communications to the spacecraft shall be through the Tug.

12) LPS is the primary mode of ground checkout.

13) Tug-to-spacecraft mating and checkout normally shall be accomplished off-pad.

14) Tug/spacecraft interface verification will normally be accomplished in the TPF.

15) A hybrid maintenance concept will be used that incorporates three modes (time, on-conditioning, and condition monitoring).

16) A Payload Preparation Room (PPR) and Payload Changeout Unit (PCU) are available for Tug use at WTR.

3.0 Operational Phase Study Elements

The 12 standard study elements are analyzed (in succeeding paragraphs) for design impacts that are to be considered during the Tug Acquisition Phase. Implementation of the design recommendation should be considered during the Tug Development Phase to preclude serious operational impact. The methods (Figure III-F-1) used in performing design impact assessments involved several steps of analysis--the first step was to identify all applicable ground operational requirements. Figures III-F-2 and III-F-3 are summary functional flows that relate to the Tug ground operations functional flow diagram generated during Task 1.0 of the Tug Fleet and Ground Operations Schedules and Controls Study. The primary source data for generation of these summary flows was contained in the documentation prepared during the performance of Task 1.0 through 6.0 of this study. Applicable data taken from other contractor's studies are referenced.

Figure III-F-1

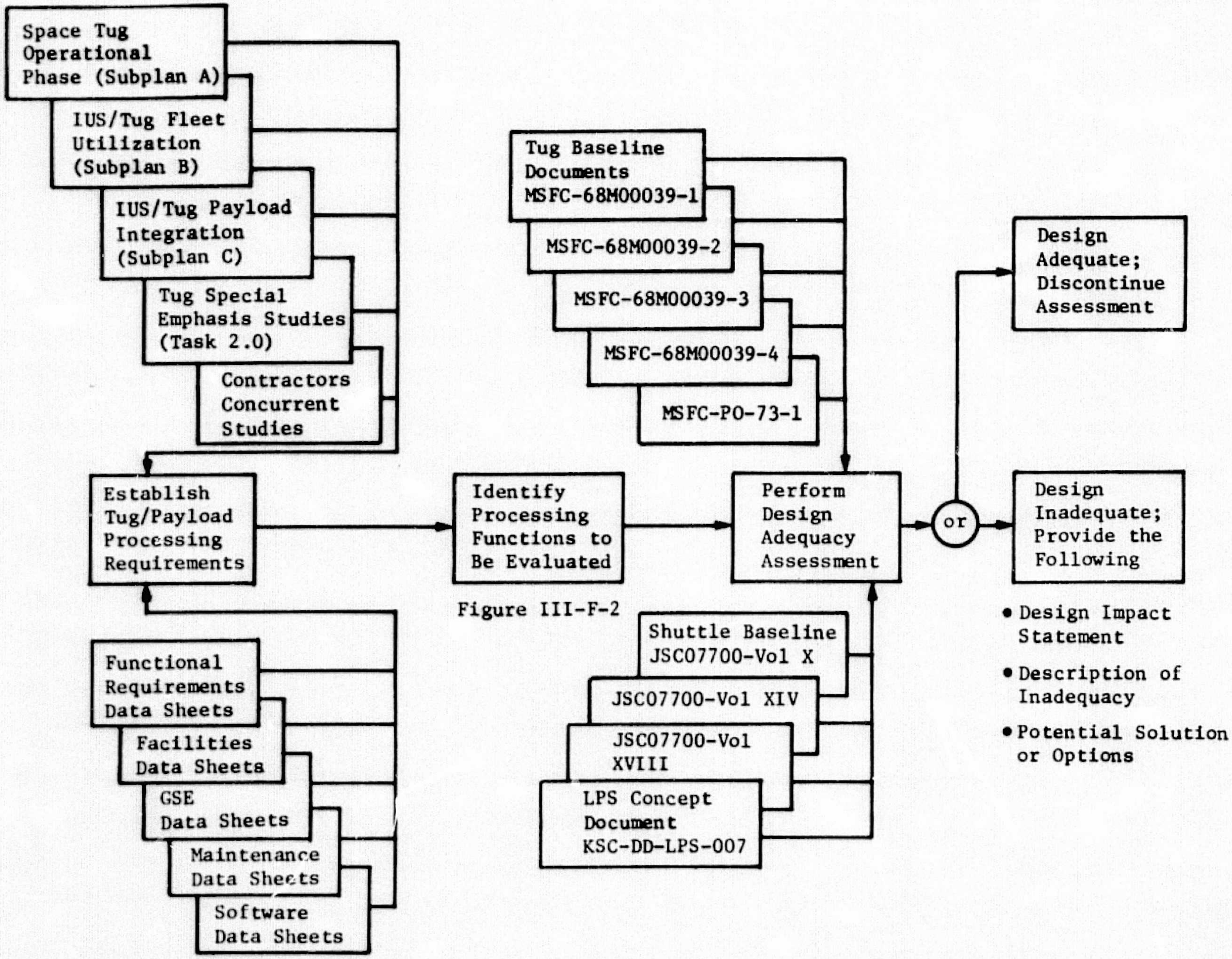
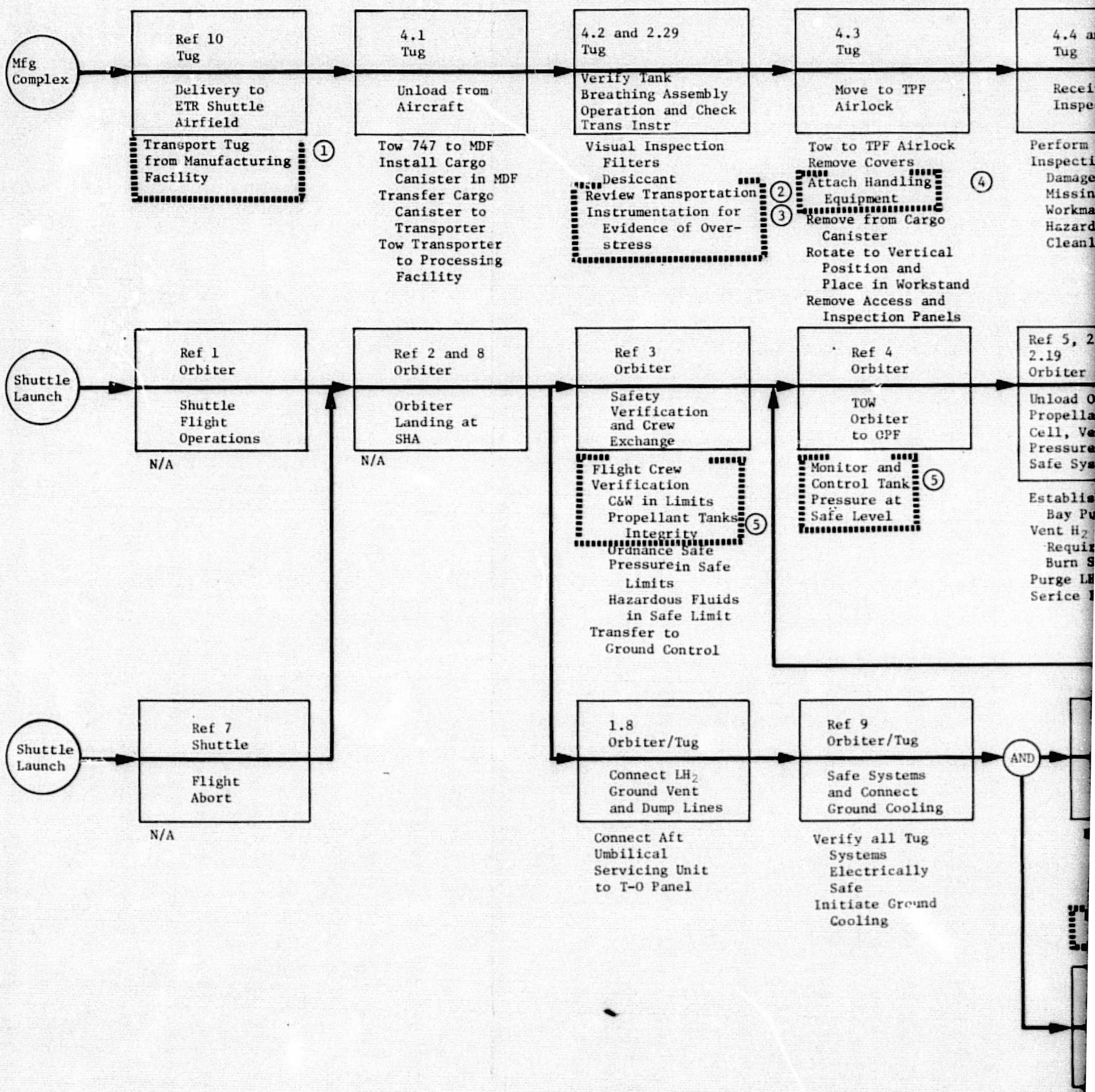
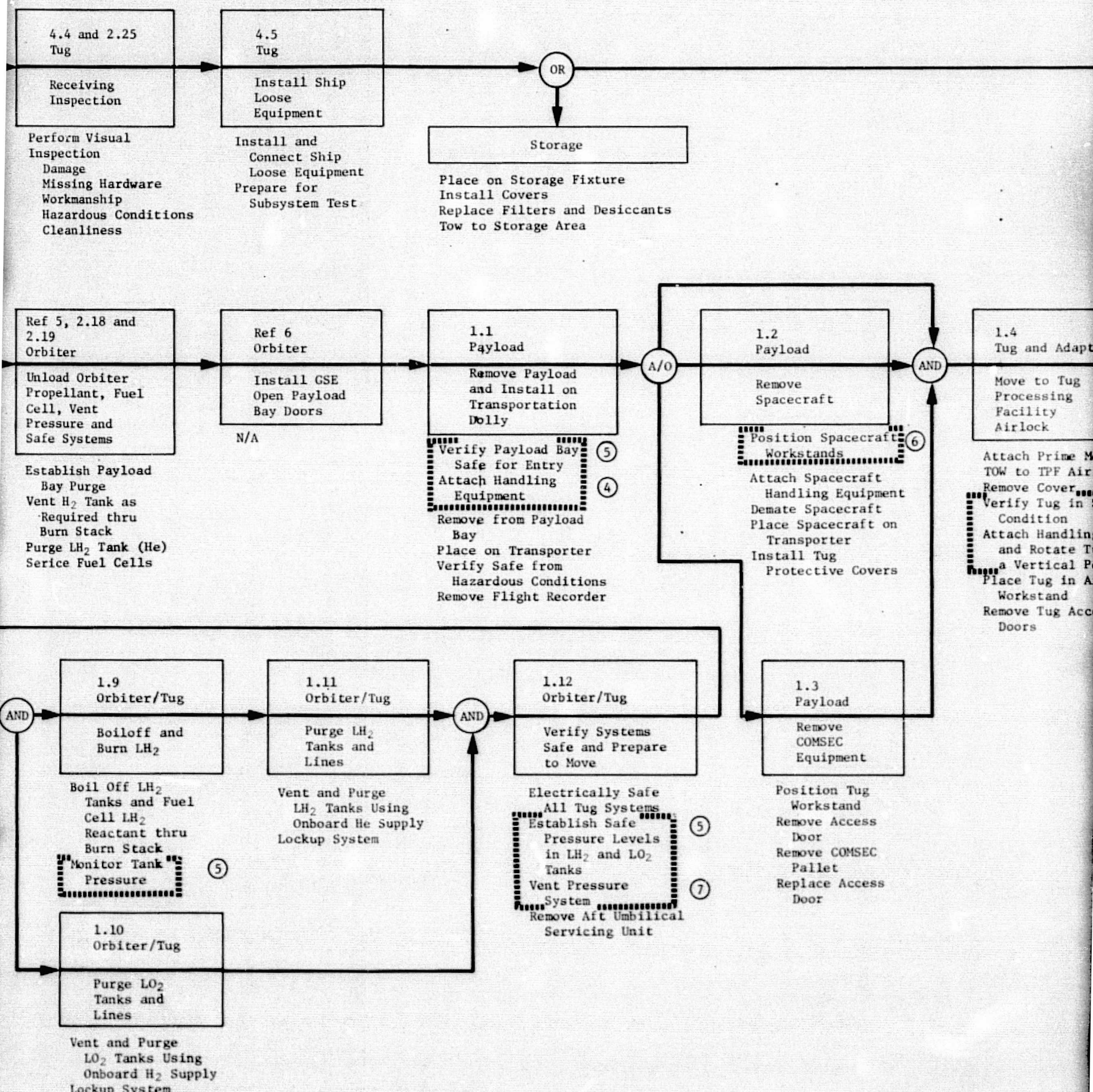


Figure III-F-1 Assessment Methods



Mfg Complex
Ref 10 Tug
Delivery to ETR Shuttle Airfield
Transport Tug from Manufacturing Facility
1
4.1 Tug
Unload from Aircraft
Tow 747 to MDF
Install Cargo Canister in MDF
Transfer Cargo Canister to Transporter
Tow Transporter to Processing Facility
4.2 and 2.29 Tug
Verify Tank Breathing Assembly Operation and Check Trans Instr
Visual Inspection
Filters
Desiccant
Review Transportation Instrumentation for Evidence of Overstress
2
3
4.3 Tug
Move to TPF Airlock
Tow to TPF Airlock
Remove Covers
Attach Handling Equipment
4
Remove from Cargo Canister
Rotate to Vertical Position and Place in Workstand
Remove Access and Inspection Panels
4.4 a
Tug
Recei
Inspe
Perform
Inspecti
Damage
Missin
Workma
Hazard
Cleanl
Shuttle Launch
Ref 1 Orbiter
Shuttle Flight Operations
N/A
Ref 2 and 8 Orbiter
Orbiter Landing at SHA
N/A
Ref 3 Orbiter
Safety Verification and Crew Exchange
Flight Crew Verification
C&W in Limits
Propellant Tanks Integrity
5
Ordnance Safe
Pressure in Safe Limits
Hazardous Fluids in Safe Limit
Transfer to Ground Control
Ref 4 Orbiter
TOW Orbiter to OPF
Monitor and Control Tank Pressure at Safe Level
5
Ref 5, 2
2.19
Orbiter
Unload O
Propella
Cell, Ve
Pressure
Safe Sys
Establis
Bay Pu
Vent H_2
Requir
Burn S
Purge LH
Serice 1
Shuttle Launch
Ref 7 Shuttle
Flight Abort
N/A
1.8 Orbiter/Tug
Connect LH_2 Ground Vent and Dump Lines
Connect Aft Umbilical Servicing Unit to T-0 Panel
Ref 9 Orbiter/Tug
Safe Systems and Connect Ground Cooling
Verify all Tug Systems Electrically Safe
Initiate Ground Cooling
AND



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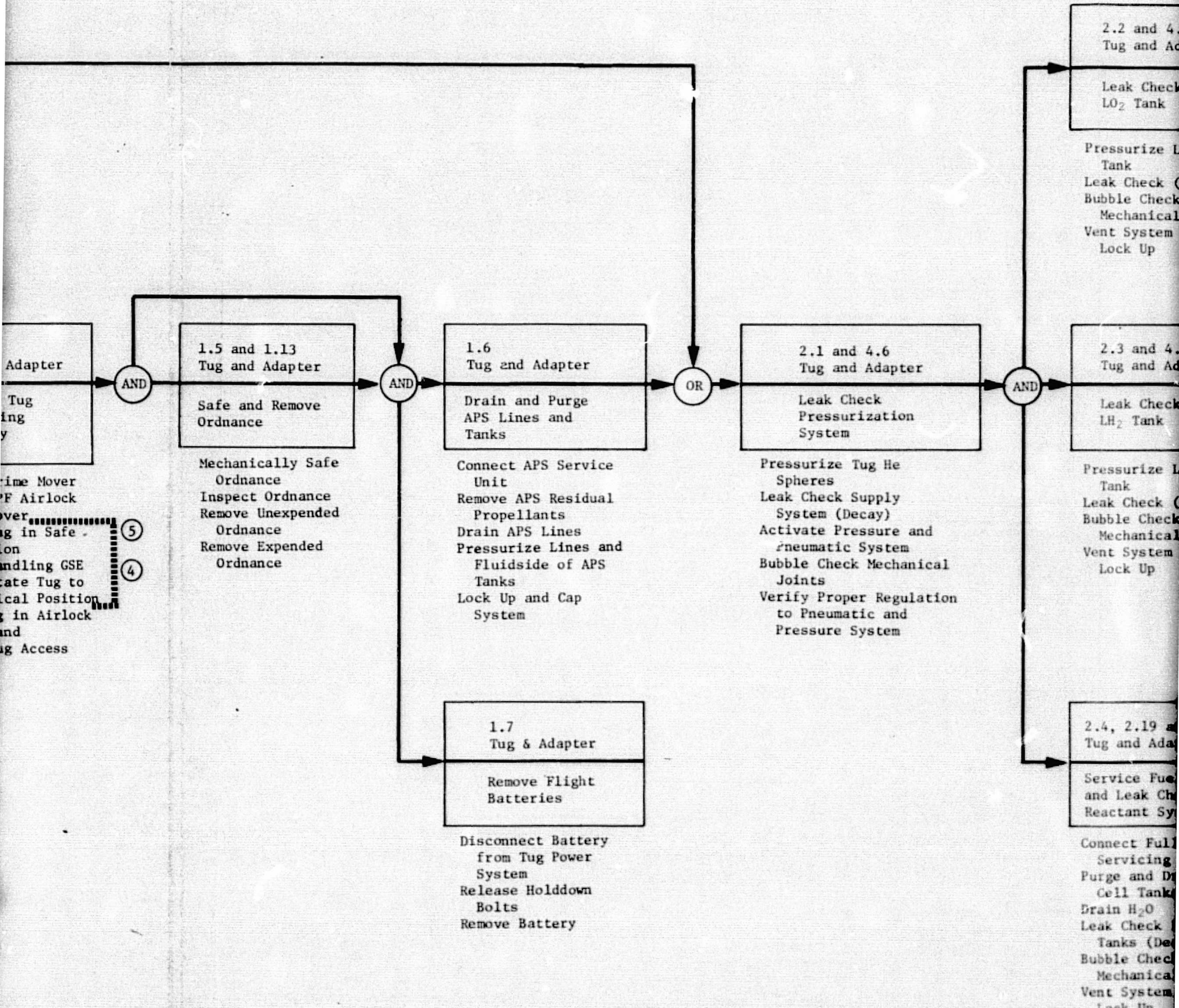

Note: This Page covers
Tug Post Landing, New Delivery and Flight Abort through Tug/Adapter Separation.

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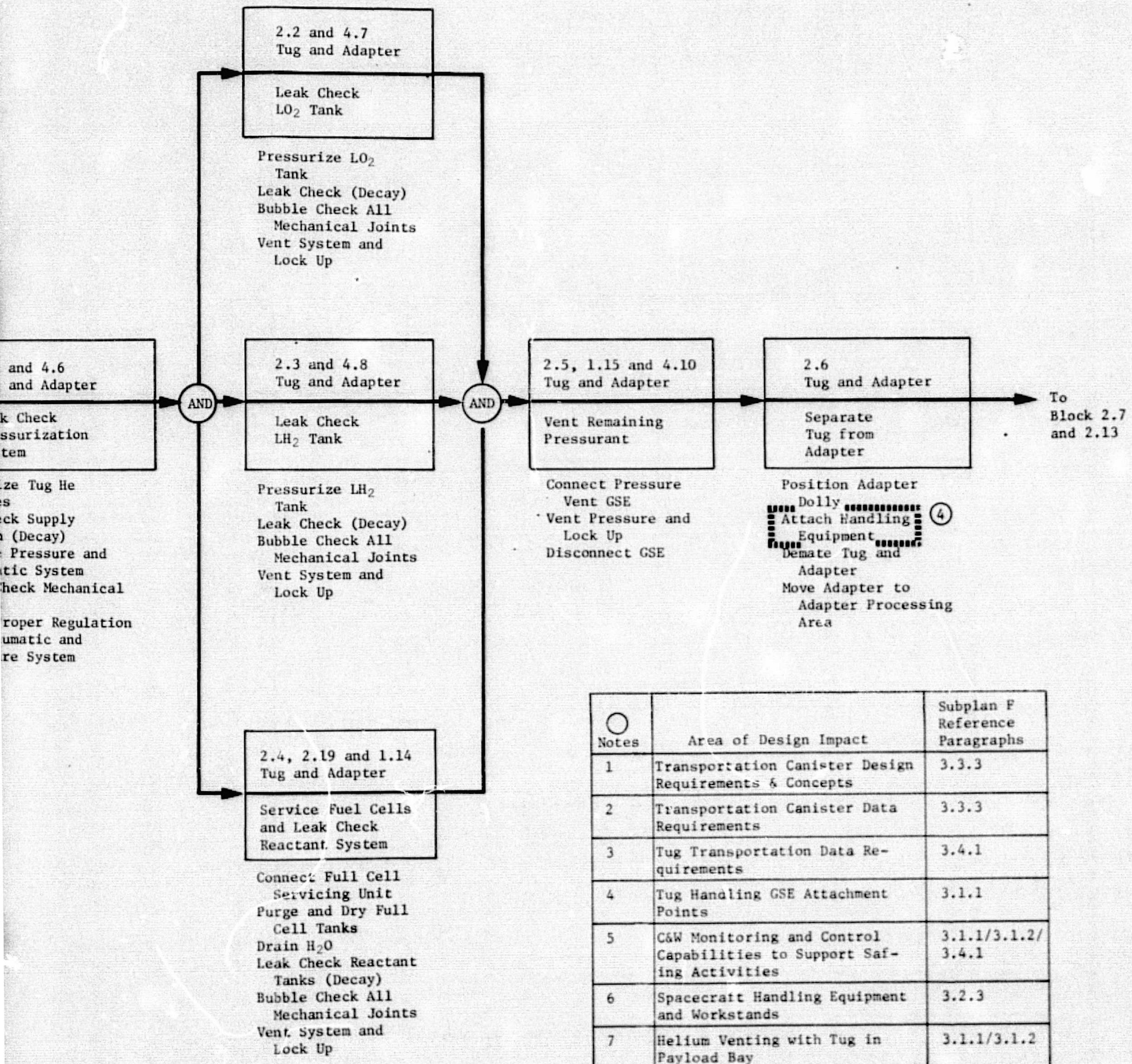
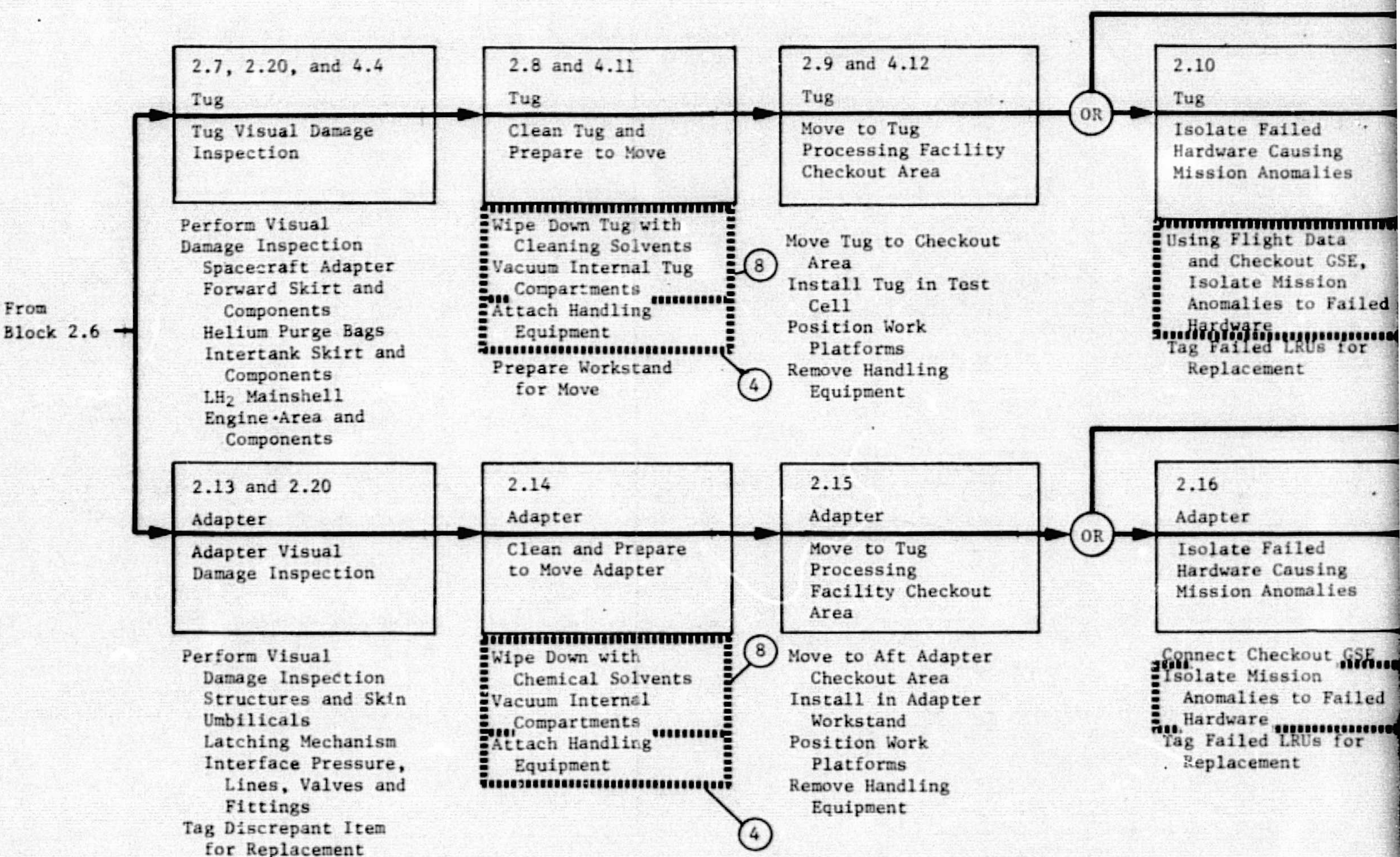
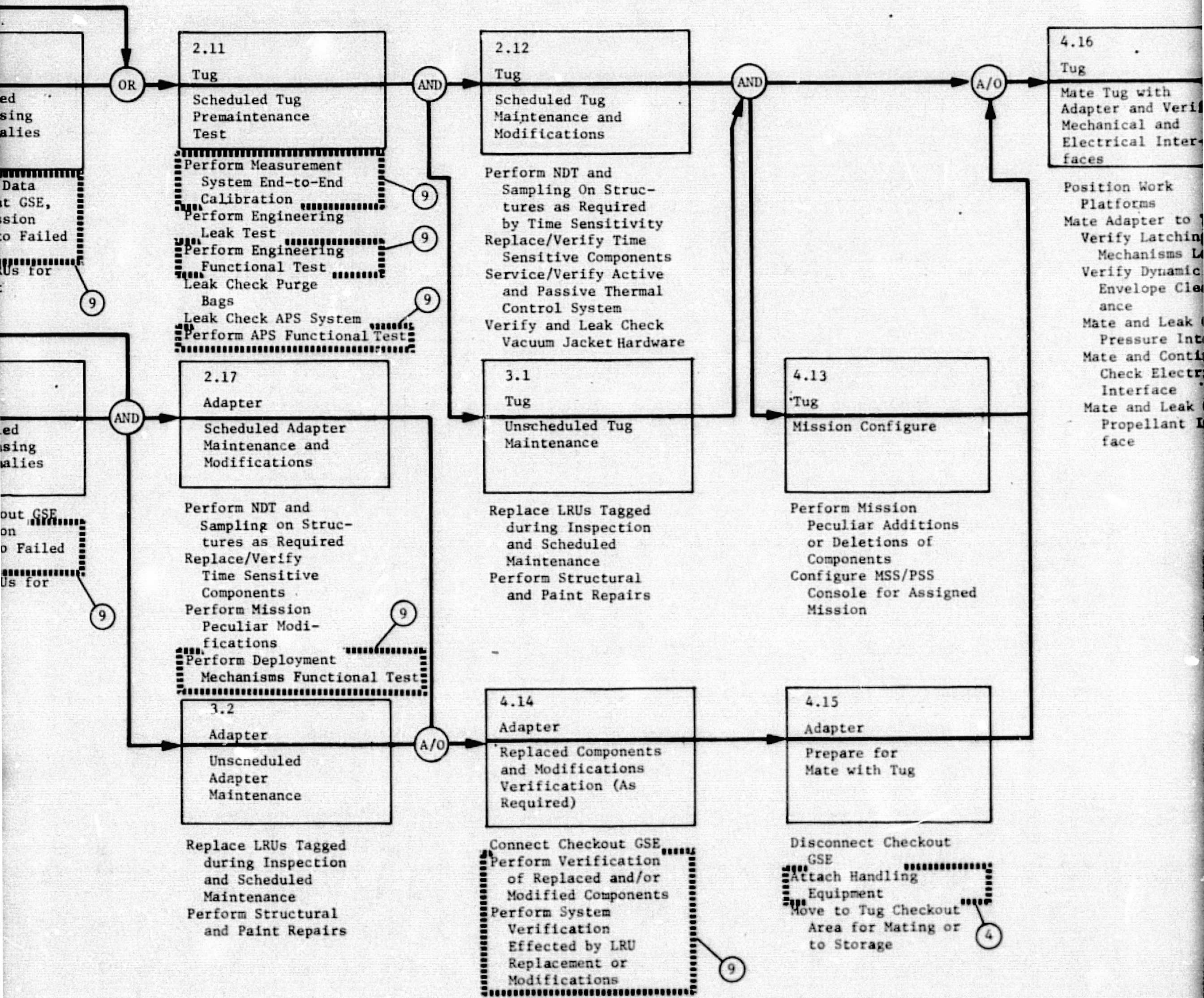


Notes	Area of Design Impact	Subplan F Reference Paragraphs
1	Transportation Canister Design Requirements & Concepts	3.3.3
2	Transportation Canister Data Requirements	3.3.3
3	Tug Transportation Data Requirements	3.4.1
4	Tug Handling GSE Attachment Points	3.1.1
5	C&W Monitoring and Control Capabilities to Support Safing Activities	3.1.1/3.1.2/ 3.4.1
6	Spacecraft Handling Equipment and Workstands	3.2.3
7	Helium Venting with Tug in Payload Bay	3.1.1/3.1.2

Note: This Page covers Tug Post Landing, New Delivery and Flight Abort through Tug/ Adapter Separation.

Figure III-F-2 Tug Processing Requirements


From Block 2.6
2.7, 2.20, and 4.4
Tug
Tug Visual Damage Inspection
Perform Visual Damage Inspection
Spacecraft Adapter
Forward Skirt and Components
Helium Purge Bags
Intertank Skirt and Components
LH2 Mainshell
Engine Area and Components
2.8 and 4.11
Tug
Clean Tug and Prepare to Move
Wipe Down Tug with Cleaning Solvents
Vacuum Internal Tug Compartments
Attach Handling Equipment
Prepare Workstand for Move
8
4
2.9 and 4.12
Tug
Move to Tug Processing Facility Checkout Area
Move Tug to Checkout Area
Install Tug in Test Cell
Position Work Platforms
Remove Handling Equipment
OR
2.10
Tug
Isolate Failed Hardware Causing Mission Anomalies
Using Flight Data and Checkout GSE, Isolate Mission Anomalies to Failed Hardware
Tag Failed LRUs for Replacement
2.13 and 2.20
Adapter
Adapter Visual Damage Inspection
Perform Visual Damage Inspection
Structures and Skin
Umbilicals
Latching Mechanism
Interface Pressure, Lines, Valves and Fittings
Tag Discrepant Item for Replacement
2.14
Adapter
Clean and Prepare to Move Adapter
Wipe Down with Chemical Solvents
Vacuum Internal Compartments
Attach Handling Equipment
8
4
2.15
Adapter
Move to Tug Processing Facility Checkout Area
Move to Aft Adapter Checkout Area
Install in Adapter Workstand
Position Work Platforms
Remove Handling Equipment
OR
2.16
Adapter
Isolate Failed Hardware Causing Mission Anomalies
Connect Checkout GSE
Isolate Mission Anomalies to Failed Hardware
Tag Failed LRUs for Replacement



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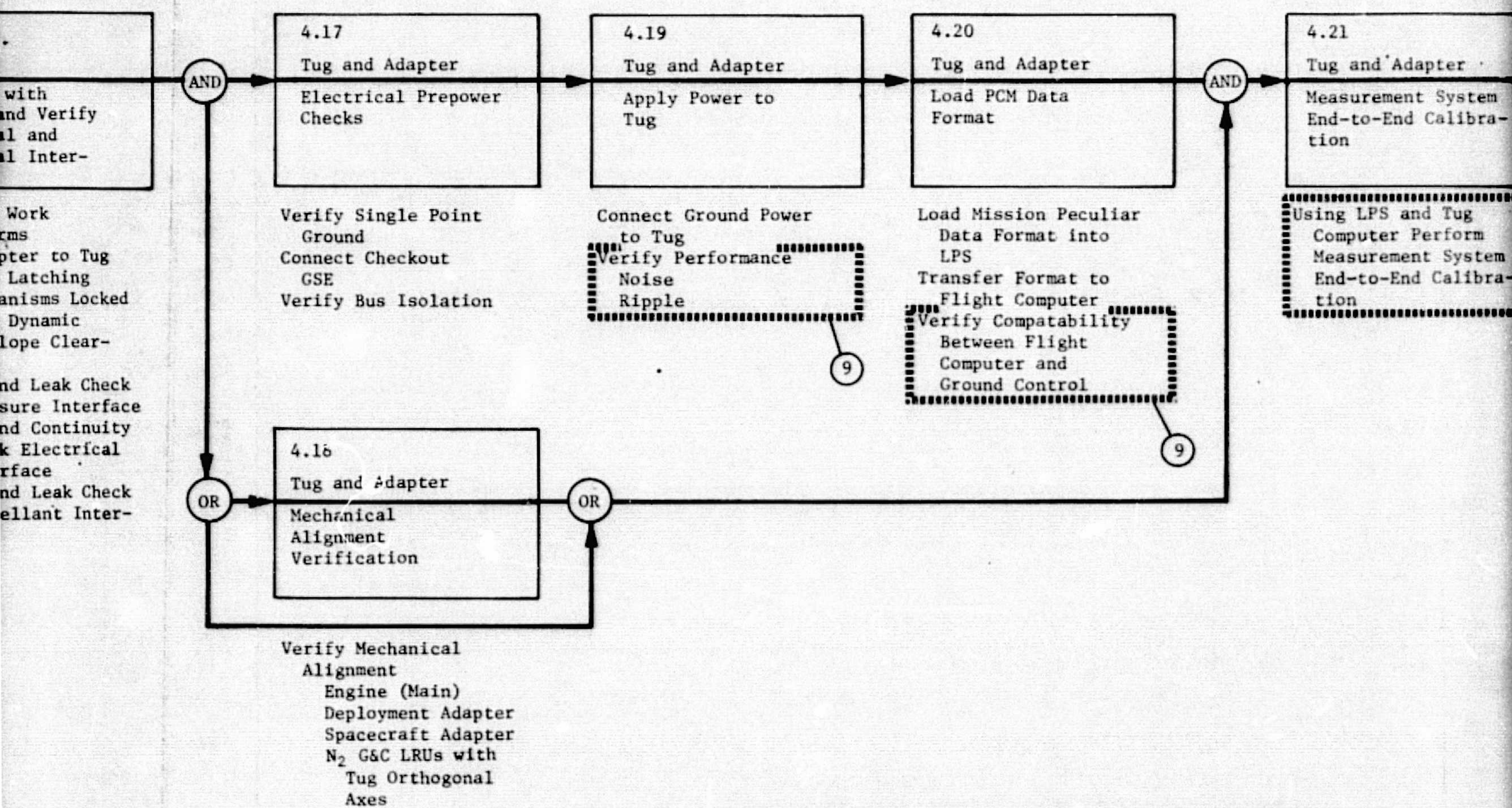

○ Notes	Areas of Design Impact	Subplan F Reference Paragraphs
4	Tug Handling GSE Attachment Points	3.1.1
8	Tug Structures Design Impact Related to Cleaning Capabilities	3.1.1
9	Ground Checkout Software Module Requirements	3.9

Note: This page covers Tug/Adapter Visual Inspection through Propellant Tank & MLI Servicing.

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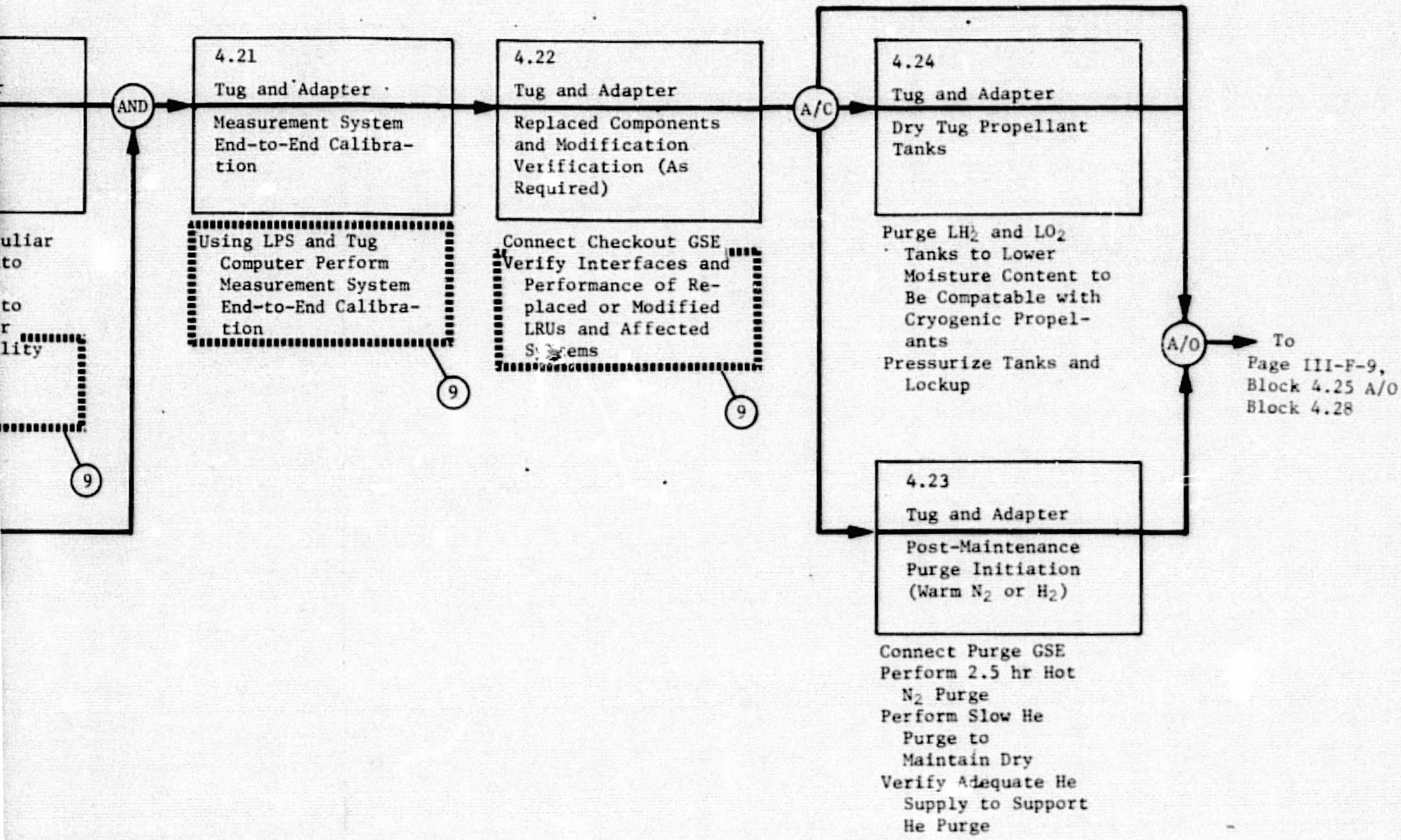
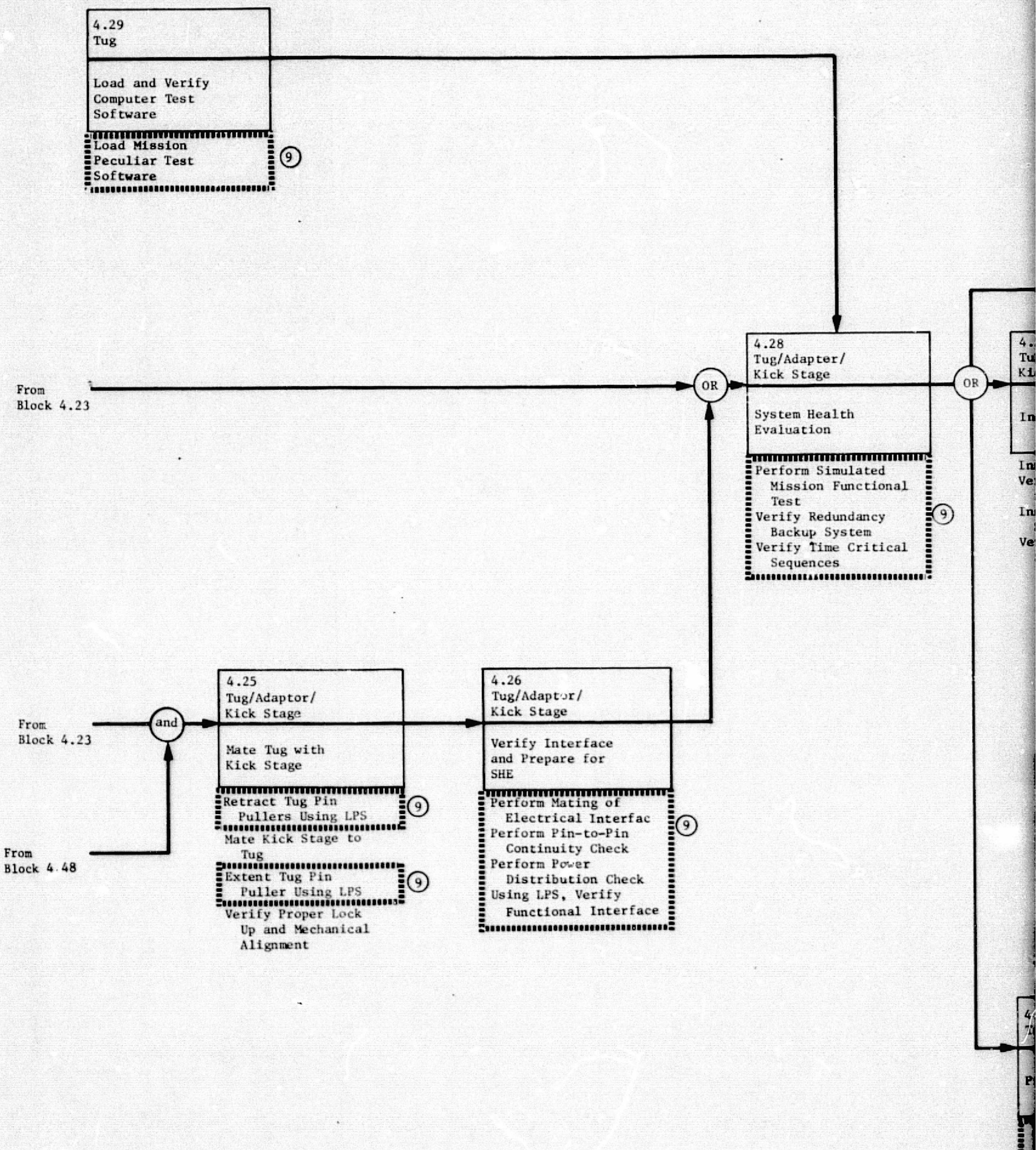


t	Subplan F Reference Paragraphs
nt	3.1.1
act il-	3.1.1
	3.9

ter

Figure III-F-2 (cont)



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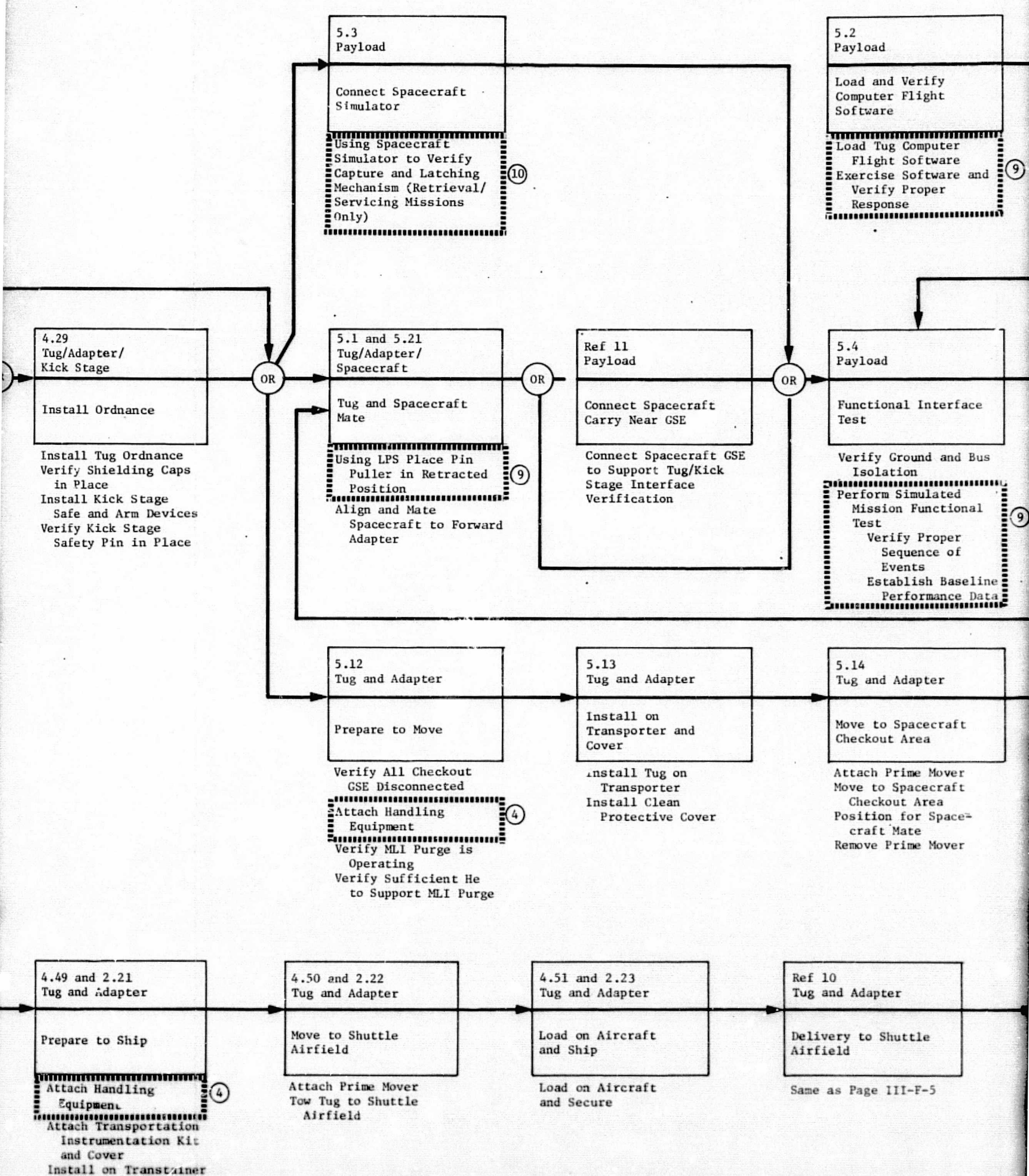
5.3
Payload
Connect Spacecraft Simulator
Using Spacecraft Simulator to Verify Capture and Latching Mechanism (Retrieval/ Servicing Missions Only)
10
5.2
Payload
Load and Verify Computer Flight Software
Load Tug Computer Flight Software
Exercise Software and Verify Proper Response
9
4.29
Tug/Adapter/ Kick Stage
Install Ordnance
Install Tug Ordnance
Verify Shielding Caps in Place
Install Kick Stage Safe and Arm Devices
Verify Kick Stage Safety Pin in Place
OR
5.1 and 5.21
Tug/Adapter/ Spacecraft
Tug and Spacecraft Mate
Using LPS Place Pin Puller in Retracted Position
9
Align and Mate Spacecraft to Forward Adapter
OR
Ref 11
Payload
Connect Spacecraft Carry Near GSE
Connect Spacecraft GSE to Support Tug/Kick Stage Interface Verification
OR
5.4
Payload
Functional Interface Test
Verify Ground and Bus Isolation
Perform Simulated Mission Functional Test
Verify Proper Sequence of Events
Establish Baseline Performance Data
9
5.12
Tug and Adapter
Prepare to Move
Verify All Checkout GSE Disconnected
Attach Handling Equipment
4
Verify MLI Purge is Operating
Verify Sufficient He to Support MLI Purge
5.13
Tug and Adapter
Install on Transporter and Cover
Install Tug on Transporter
Install Clean Protective Cover
5.14
Tug and Adapter
Move to Spacecraft Checkout Area
Attach Prime Mover
Move to Spacecraft Checkout Area
Position for Spacecraft Mate
Remove Prime Mover
4.49 and 2.21
Tug and Adapter
Prepare to Ship
Attach Handling Equipment
4
Attach Transportation Instrumentation Kit and Cover
Install on Transtainer
4.50 and 2.22
Tug and Adapter
Move to Shuttle Airfield
Attach Prime Mover
Tow Tug to Shuttle Airfield
4.51 and 2.23
Tug and Adapter
Load on Aircraft and Ship
Load on Aircraft and Secure
Ref 10
Tug and Adapter
Delivery to Shuttle Airfield
Same as Page III-F-5

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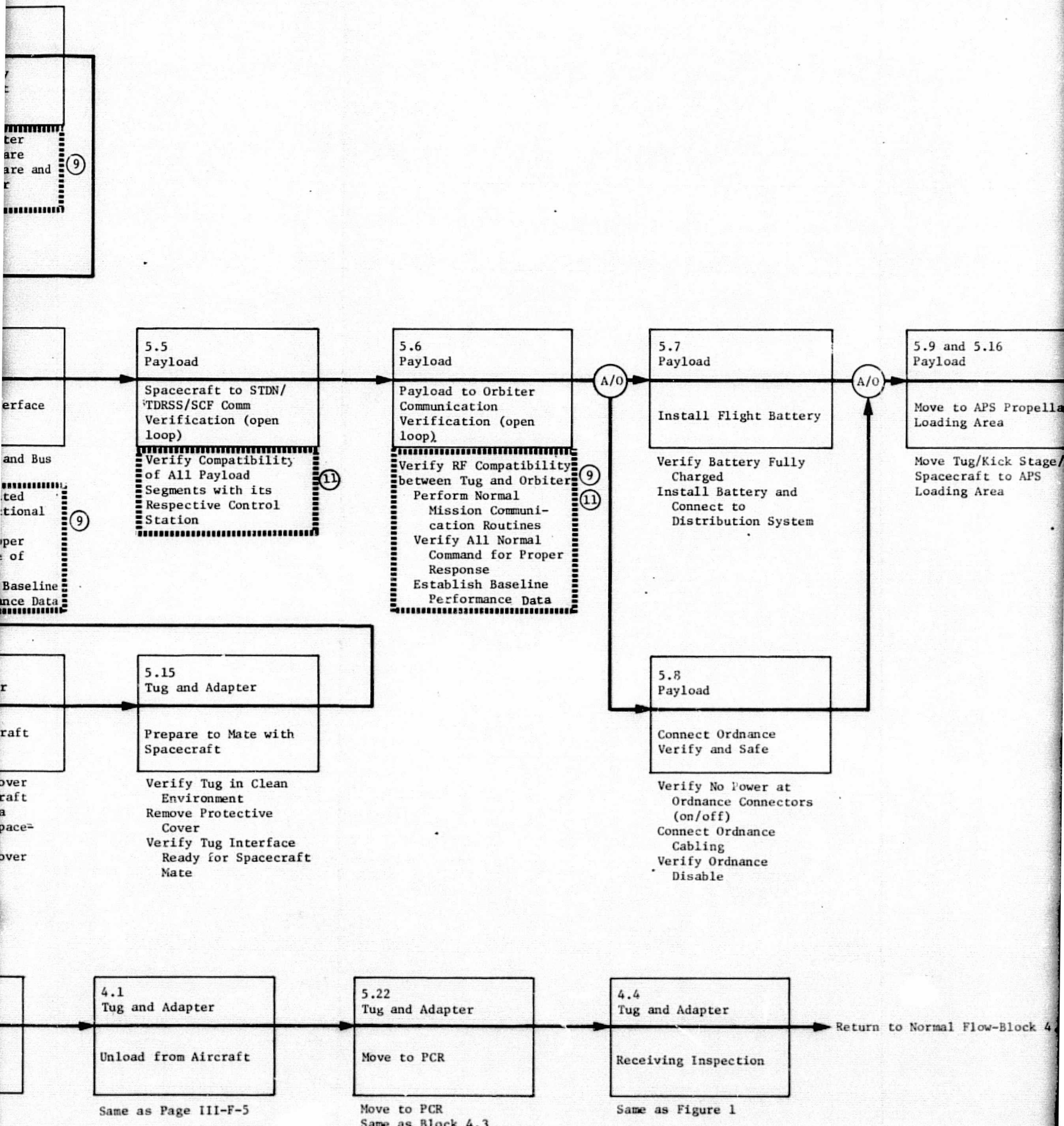

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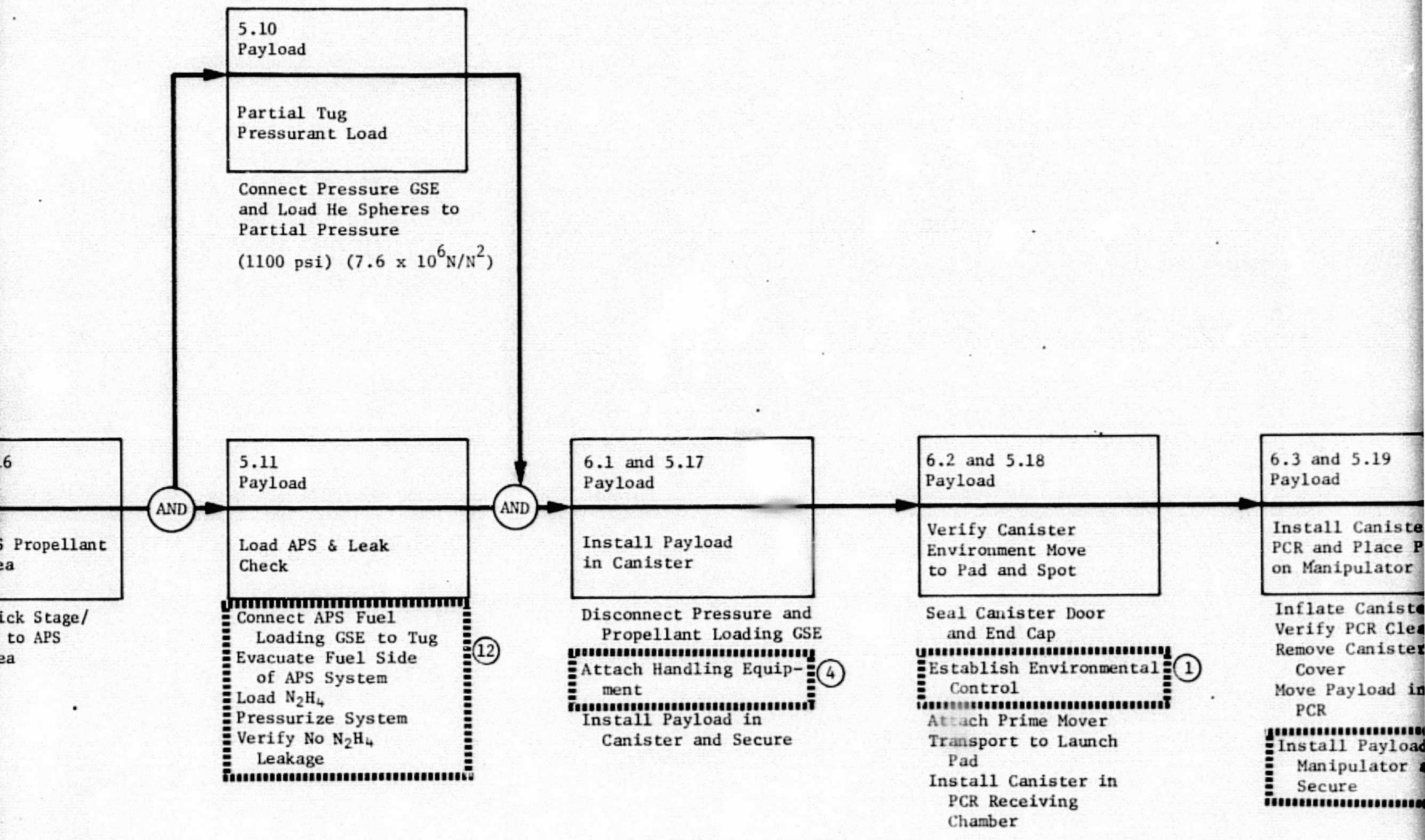

Note:	Area of Design Impact	[illegible]ference [illegible]ragraphs
1	Transportation Canister Design Requirements & Concepts	[illegible].3.3
4	Tug Handling GSE Attachment Points	3.1.1
9	Ground Checkout Software Module Requirements	3.9
10	Spacecraft Simulator Requirements	3.2.3
11	Ground Checkout RF Requirements to Support Tug/Payload Processing	3.2.3
12	Propellant and Pressurant Loading Provision	3.1.1/3.1.2/ 3.2.3 & 3.2.4

-Block 4.28

Note: This page covers Tug/Adapter/Kick Stage Mating through PCR Installation

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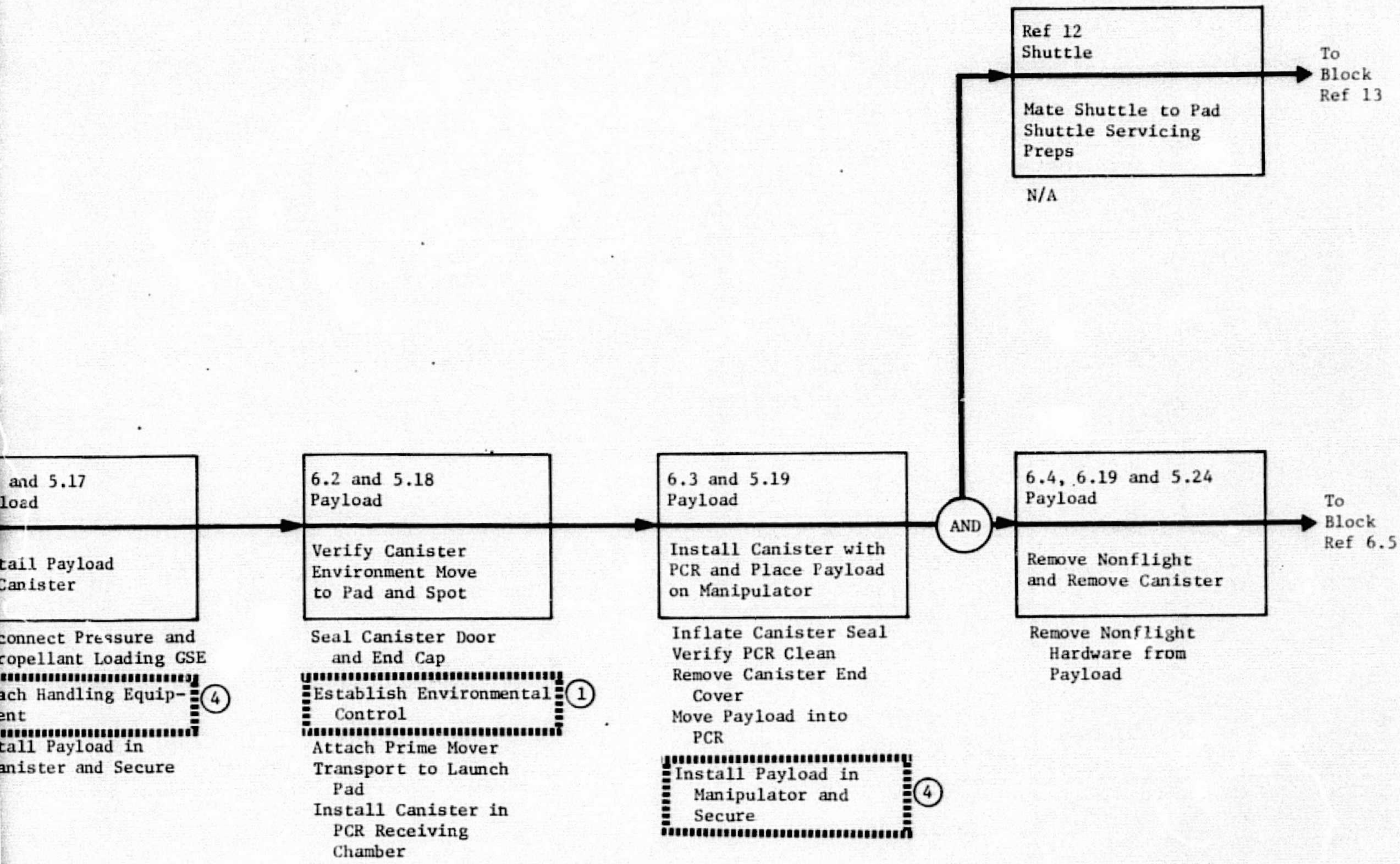

Note:	Area of Design Impact	Reference Paragraphs
1	Transportation Canister Design Requirements & Concepts	3.3.3
4	Tug Handling GSE Attachment Points	3.1.1
9	Ground Checkout Software Module Requirements	3.9
10	Spacecraft Simulator Require-ments	3.2.3
11	Ground Checkout RF Requirements to Support Tug/Payload Proc-essing	3.2.3
12	Propellant and Pressurant Loading Provision	3.1.1/3.1.2/ 3.2.3 & 3.2.4

Note: This page covers Tug/Adapter/ Kick Stage Mating through PCR Installation

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Figure III-F-2 (cont)

From Block Ref 12

Ref 13
Shuttle
Launch Readiness Verification

N/A

Ref 14
Shuttle
Purge and Sample Facility LH_2 and LO_2 System

N/A

Ref 16
Shuttle
Cabin Closeout

N/A

Ref 15
Payload
Final Spacecraft Service and Flight Preparation (Nonfunctional)

N/A

From Block Ref 6.4

6.5
Facility/Shuttle
Extend PCR Open Payload Bay Doors

- Extend PCR to Mate Position
- Install Work Platforms
- Wipe Down Orbiter Doors and Seals
- Remove Work Platforms
- Open Bay Doors
- Establish Common Environment

6.6
Payload/Shuttle
Mate Payload with Orbiter

- Align Payload Guides
- Mate Payload to Orbiter
- Verify Retention System Locked
- Mate Interface Connectors

13

6.7
Payload/Shuttle
Payload-Orbiter Interface Verification

- Leak Check Pressure and Propellant Connects (Decay)
- Perform Electrical Continuity Checks
- Apply Power to Tug
- Establish MLI Purge

9

AND

6.8
Payload/Shuttle
Payload Measurement Profile

- Power Up Tug and Establish Measurement System Baseline Performance Data

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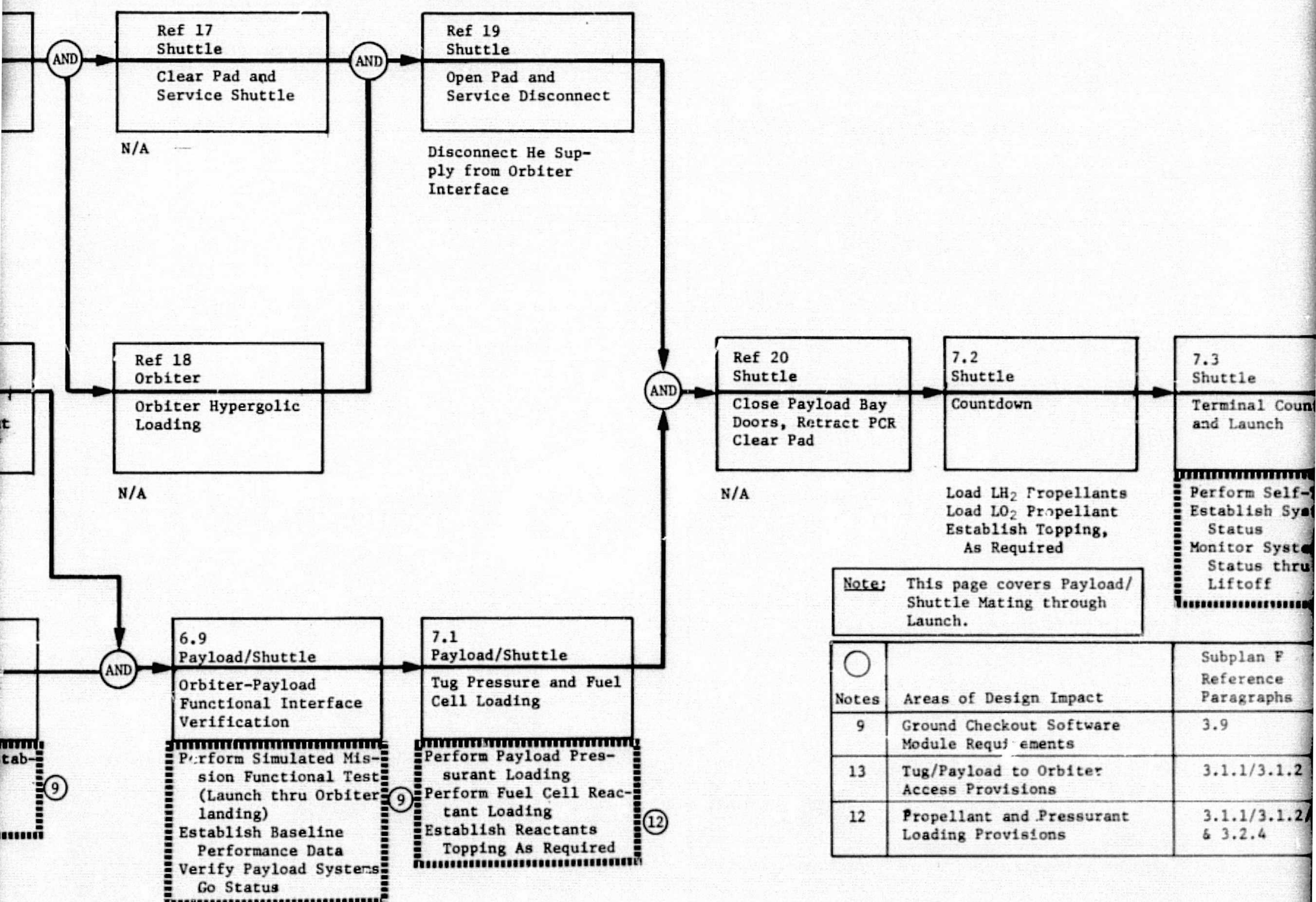

Note: This page covers Payload/Shuttle Mating through Launch.

Notes	Areas of Design Impact	Subplan F Reference Paragraphs
9	Ground Checkout Software Module Requirements	3.9
13	Tug/Payload to Orbiter Access Provisions	3.1.1/3.1.2
12	Propellant and Pressurant Loading Provisions	3.1.1/3.1.2/ & 3.2.4

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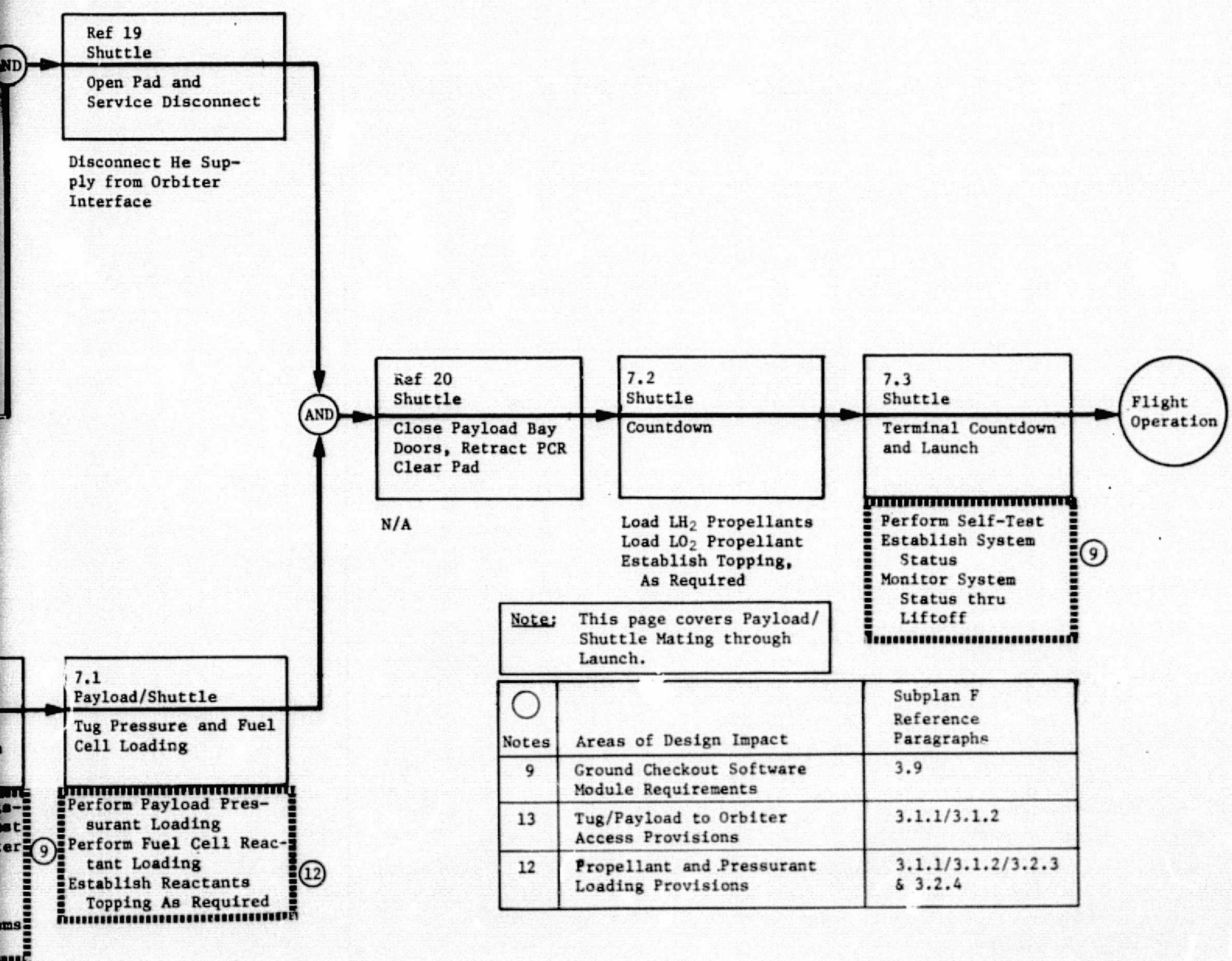

◯ Notes	Areas of Design Impact	Subplan F Reference Paragraphs
9	Ground Checkout Software Module Requirements	3.9
13	Tug/Payload to Orbiter Access Provisions	3.1.1/3.1.2
12	Propellant and Pressurant Loading Provisions	3.1.1/3.1.2/3.2.3 & 3.2.4

Figure III-F-2 (concl)

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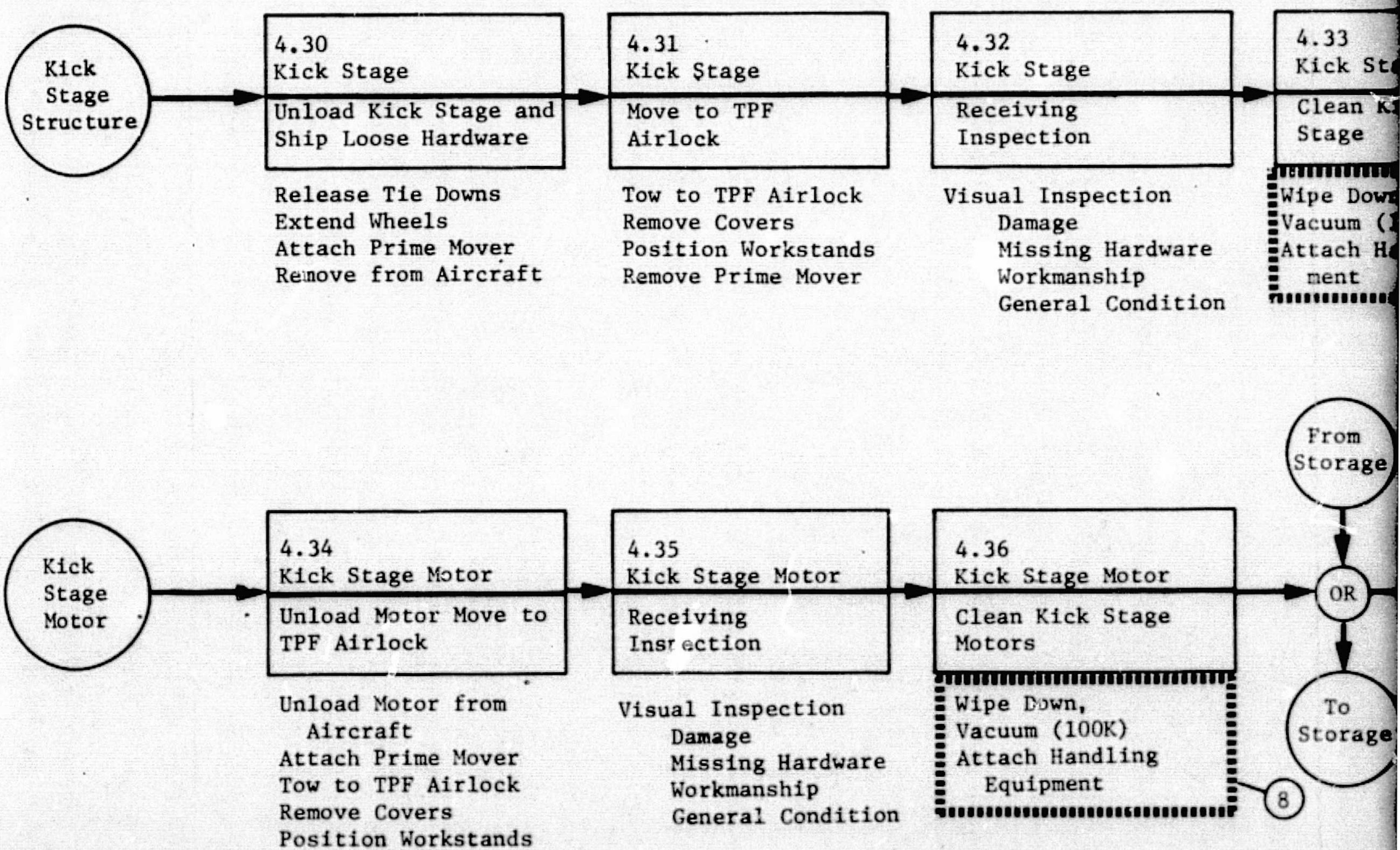

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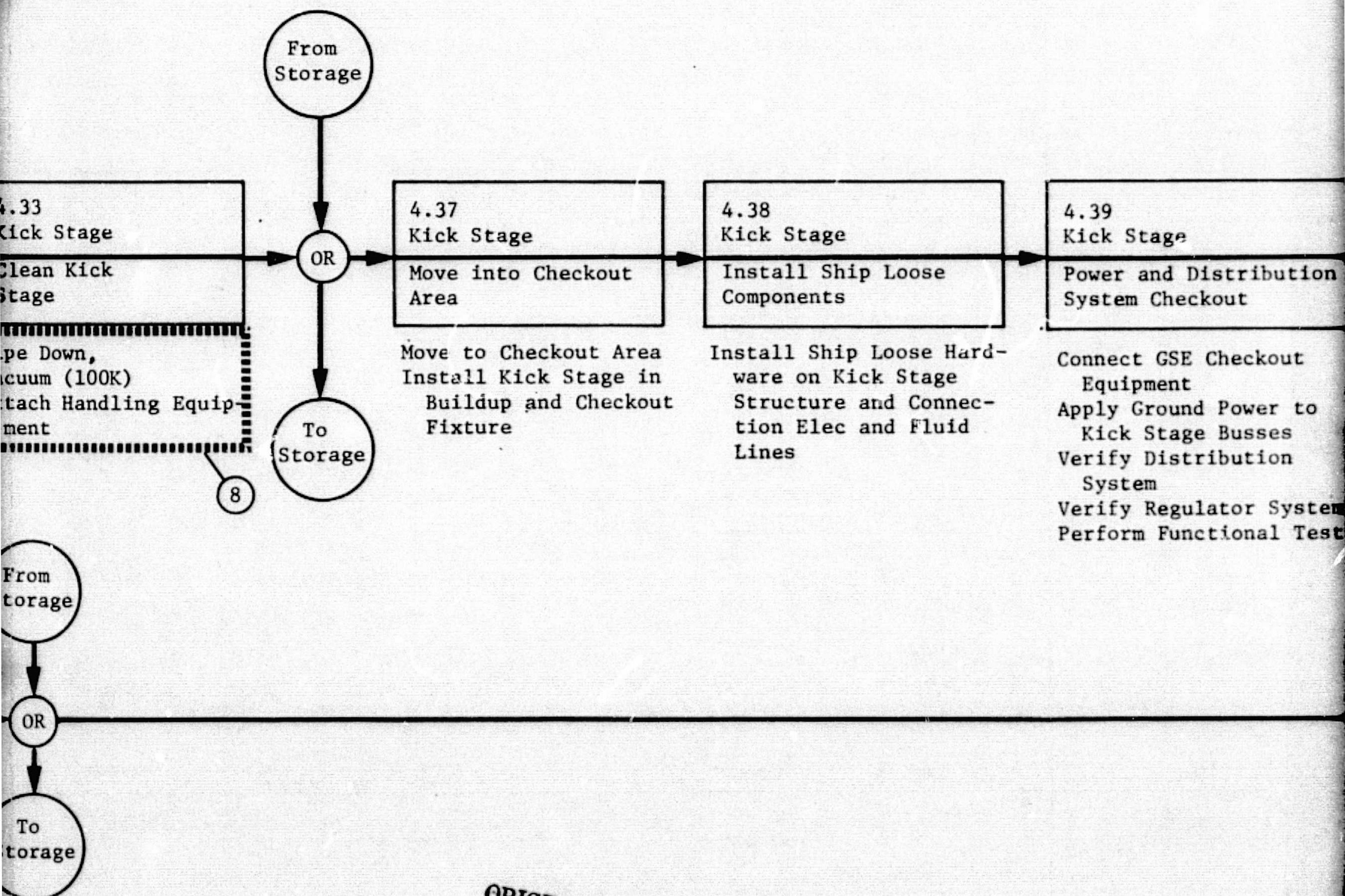

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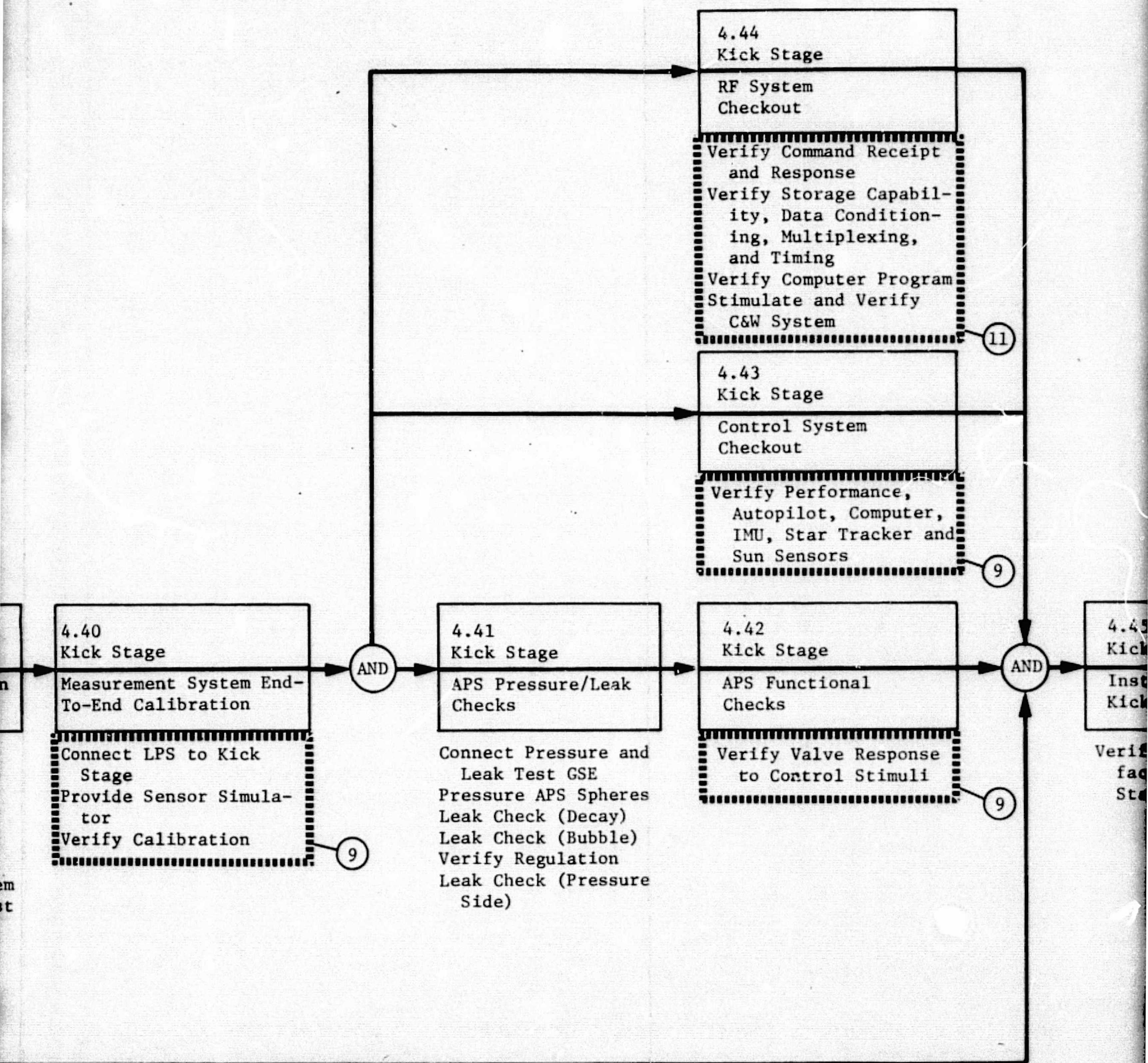

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tor in

anical Inter-
or to Kick

4.46.
Kick Stage

Combined Systems
Test Preparations

Establish Proper Kick
Stage Configuration
Connect GSE Required
for CST

4.47
Kick Stage

Combined Systems
Test

Perform Mission Simulation, Countdown thru Spacecraft Separation

9

4.48
Kick Stage

Remove GSE Prepare to
Mate with Tug

Disconnect GSE
Perform Final Visual
Inspection
Install Handling GSE
Move to Tug Processing
Area

To Tug
Processing

) es	Areas of Design Impact	Subplan F Reference Paragraphs
8	Tug Structures Design Impact Related to Cleaning Capabilities	3.1.1
9	Ground Checkout Software Module Requirements	3.9
1	Ground Checkout RF Requirement to Support Tug/Payload Processing	3.2.3

Figure III-F-3 Kick Stage Processing Requirements

After completion of the requirements identification, the individual requirements were compared to Shuttle/Orbiter and Tug design data. This assessment was completed to determine if the Orbiter payload accommodations capability, Tug baseline design, facilities, GSE, and software was adequate to accomplish the operational requirements. The process required tracing the function to or from the Tug-involved hardware through the Orbiter interface or to the GSE or facility interface (as applicable) to form a closed or completed loop. At the same time, such considerations as safety, transportation, and maintainability factors were included for complete assessment of design impact. If the available data indicated that the requirement could be accomplished, the item was considered as having no design impact. However, if the converse was true, the apparent design problem was assigned to the applicable study element and a solution or recommendation as to which STS element change should be implemented (i.e., the Shuttle/Orbiter, Tug, Facility, or GSE). Where a potential design problem existed, the specific function on Figures III-F-2, and III-F-3 are contained in a shadow box and the discussion paragraph is identified. A matrix is located in paragraph 5.0 that summarizes all the various types of design impacts.

Where the selected change element is either facility, GSE, or software, the solution will be identified as a design requirement in lieu of a design change inasmuch as these items do not have an established design or configuration baseline.

3.1 Tug Ground Operations Functional Flow

The ground operations functional flow developed during task 1.0 of the Tug Fleet and Ground Operations Schedules and Controls Study and other flow diagrams developed during performance of tasks 2.0 through 6.0 of the aforementioned study, were reviewed for operational requirements. Those operational requirements that presented potential design impact related purely to the Tug or Shuttle/Orbiter functional performance are covered in subsequent paragraphs. Other problems/requirements related to facilities, GSE, transportation, safety, software, and logistics/maintenance are covered in their appropriate paragraphs.

3.1.1 Tug Design Impacts - The following paragraphs define those areas of design concerns related to the Tug, and include consideration of functional capability and access that should be considered during the Tug design/development phase.

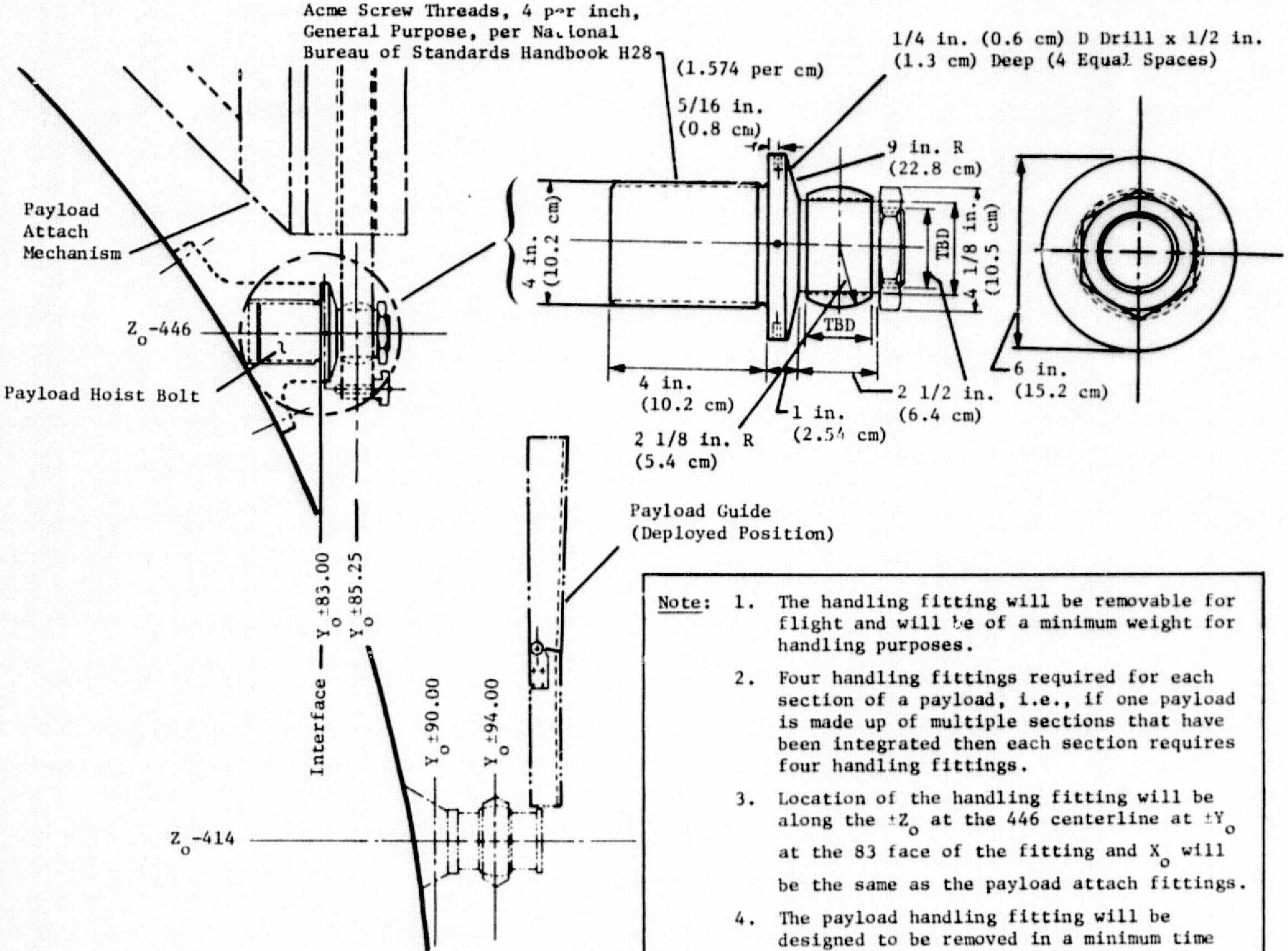
3.1.1.1 Handling Equipment Attachment Provisions - The current baseline configuration document, MSFC 68M00039-2, identifies a conceptual design for attachment of the Tug in the Orbiter payload bay. During a review of this design it becomes apparent that these attachment mechanisms do not have the capacity to accommodate both the handling GSE and normal supporting mechanisms at the same time. The condition leads to the conclusion that additional attachment provisions must be supplied either as bolt-on GSE or an integral flyaway part of the Tug. Although the KSC bolt-on concept (Figure III-F-4) provides one solution to this problem, the method would mean that additional Tug superstructure would have to be added to the Tug airframe to support the loads in the region of the bolt-on mechanism. Another possible solution would be to add a second set of attachments adjacent to the existing attachment provisions using the same load bearing structure. This dual function on the same structural members is made possible by the fact that only one set of attachment points would be carrying the handling load at a given time, therefore allowing the same support structure to handle the load in either mode. Figure III-F-5 illustrates this concept of handling attachment provisions.

3.1.1.2 C&W Monitoring and Functional Reaction Capabilities Related to Safing Activities - The following measurements should be considered condidates for C&W monitoring with control capabilities provided for appropriate subsystem reactions to the hazardous condition.

1) LH_2 and LO_2 Temperature and Pressure Monitoring and Control - In the case of the LH_2 and LO_2 tanks, external temperatures and internal pressures will be monitored. The current propellant tank vent and relief system is controlled by actuation of solenoid control valves that are controlled through the output of pressure transducers under normal operating conditons. To enable contingency responses, a manual remote control override capability should be added to the system.

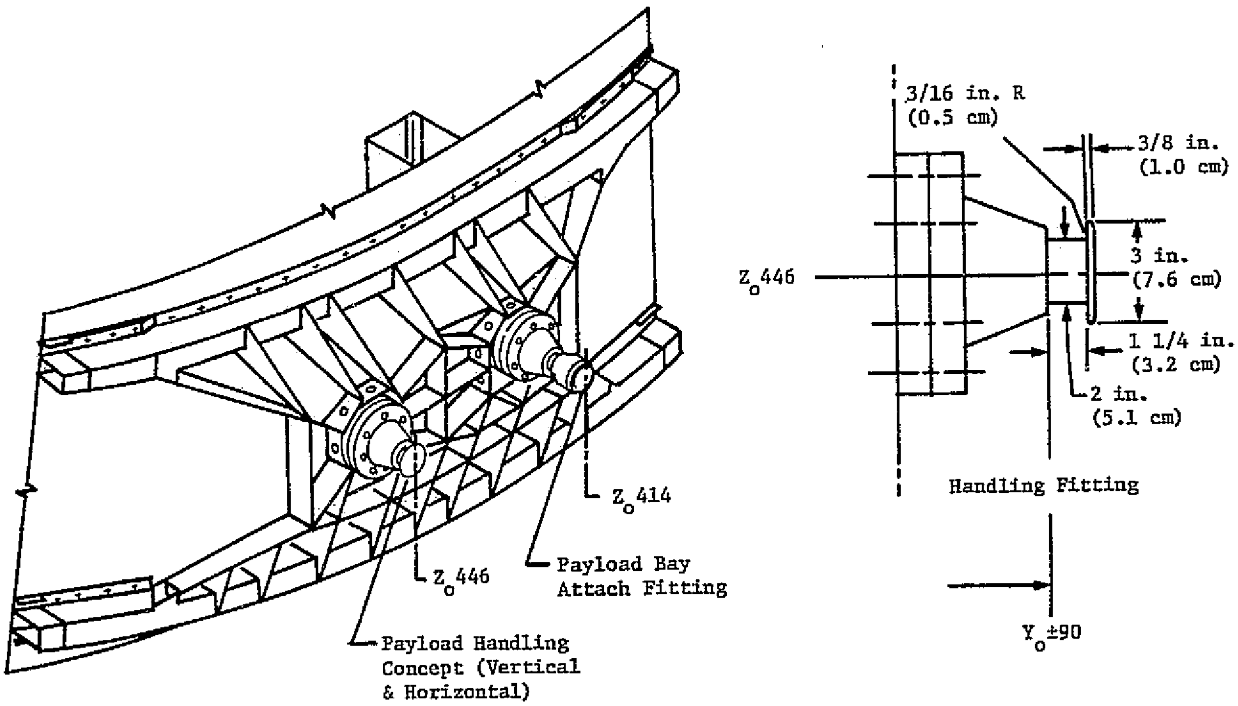
2) Helium Pressurization System Monitoring - The helium pressurization system pressure should be monitored. Adequate control appears to be available to vent the three Helium spheres through the fill line should an overpressure and a failure in the mechanical vent occur simultaneously.

3.1.1.3 Helium Venting of Tug/Payload - Due to the degrading effects on certain spacecraft and Tug hardware it is recommended that all spacecraft and Tug helium venting be accomplished through an Orbiter overboard dump.



Note:
1. The handling fitting will be removable for flight and will be of a minimum weight for handling purposes.
2. Four handling fittings required for each section of a payload, i.e., if one payload is made up of multiple sections that have been integrated then each section requires four handling fittings.
3. Location of the handling fitting will be along the $\pm Z_o$ at the 446 centerline at $\pm Y_o$ at the 83 face of the fitting and X_o will be the same as the payload attach fittings.
4. The payload handling fitting will be designed to be removed in a minimum time frame with commercial tools.

Figure III-F-4 Bolt-On Handling Attachment Points



Note: Handling Attachment Point Integrated into Normal Tug Structure

Figure III-F-5 Integrated Handling Attachment Point

3.1.1.4 *Tug Structures Design Impact Related to cleaning Capabilities* - Subplan A (task 1.0) identifies two possible processing techniques for the Tug. These are the 100,000 clean processing and the factory clean concept. In either case a requirement exists to accomplish a solvent wipe down and vacuuming of external surfaces, internal structures, and equipment compartments. To simplify and make more effective these cleaning operations, particularly the internal structures and surfaces, design consideration should be given to fabrication and jointing techniques. It must be kept in mind that all Tug surfaces are required to be cleaned to "visibly clean;" therefore, such things as sealing of faying surfaces, smooth grinding of bonded joints, and avoidance of sharp or narrow crevices must be considered during structures design. During compartment design and equipment location planning, adequate access for cleaning equipment must be considered.

3.1.1.5 *Tug/Payload Mating to Orbiter Access Provisions* - During evaluation of the Tug-to-Orbiter mating functions it became apparent that some access problems exist. These problems were primarily related to connection and checkout of fluid and electrical umbilicals. The current Tug baseline configuration and the Orbiter/payload accommodations documentation locate these

C-6

umbilical connections in the lower two quadrants of the Tug and the payload bay. This condition makes it almost impossible for a man to accomplish manual umbilical connections. With this extremely marginal access the probability of damage to the payload bay liner and Tug hardware in the near vicinity is greatly increased. The GDC-Convair Aerospace Division recently submitted several deployment options, all of which somewhat improved, but did not eliminate, the mate/demate access problem. Of the three options submitted, deployment with a pivoting deployment adapter, was considered the most acceptable for reasons other than access. We believe the concept is preferred for the following reasons: (1) the concept provides a higher level of confidence in the ability to perform actual Tug deployment, because it provides redundant actuators and the use of the RMS as a backup deployment system; (2) it simplifies the Tug shell structural design by providing additional attachment points; (3) it uses existing Orbiter mechanisms for accomplishing retrieval alignment; and (4) it provides hard-wired C&W monitoring capability while the Tug is being rotated out of the cargo bay. However, this approach does not solve the umbilical connection access problem. With the incorporation of this deployment option the problem of access could be resolved by relocation of Tug umbilical connectors and the Orbiter service panels to the upper two quadrants of the Tug and the payload bay.

Figures III-F-6 through III-F-9 identify and highlight the access concerns related to umbilical connections, whereas Figure III-F-10 provides an illustration of the changes to the Tug that could solve the problem.

3.1.1.6 Propellants and Pressurants Loading Provisions - During the performance of special emphasis assessment related to propellant loading considerations, a philosophy or technique for accomplishing propellant and pressurant servicing was evolved for the Space Tug. The concepts related to APS, MPS, and fuel cell reactant loading activities. During evaluation of these approaches, certain design inadequacies and functional simplification techniques became apparent that would generate changes in the baseline Tug, Orbiter, GSE, and facilities. The following paragraph defines the changes associated with the Space Tug. Other changes are covered in appropriate sections of this subplan.

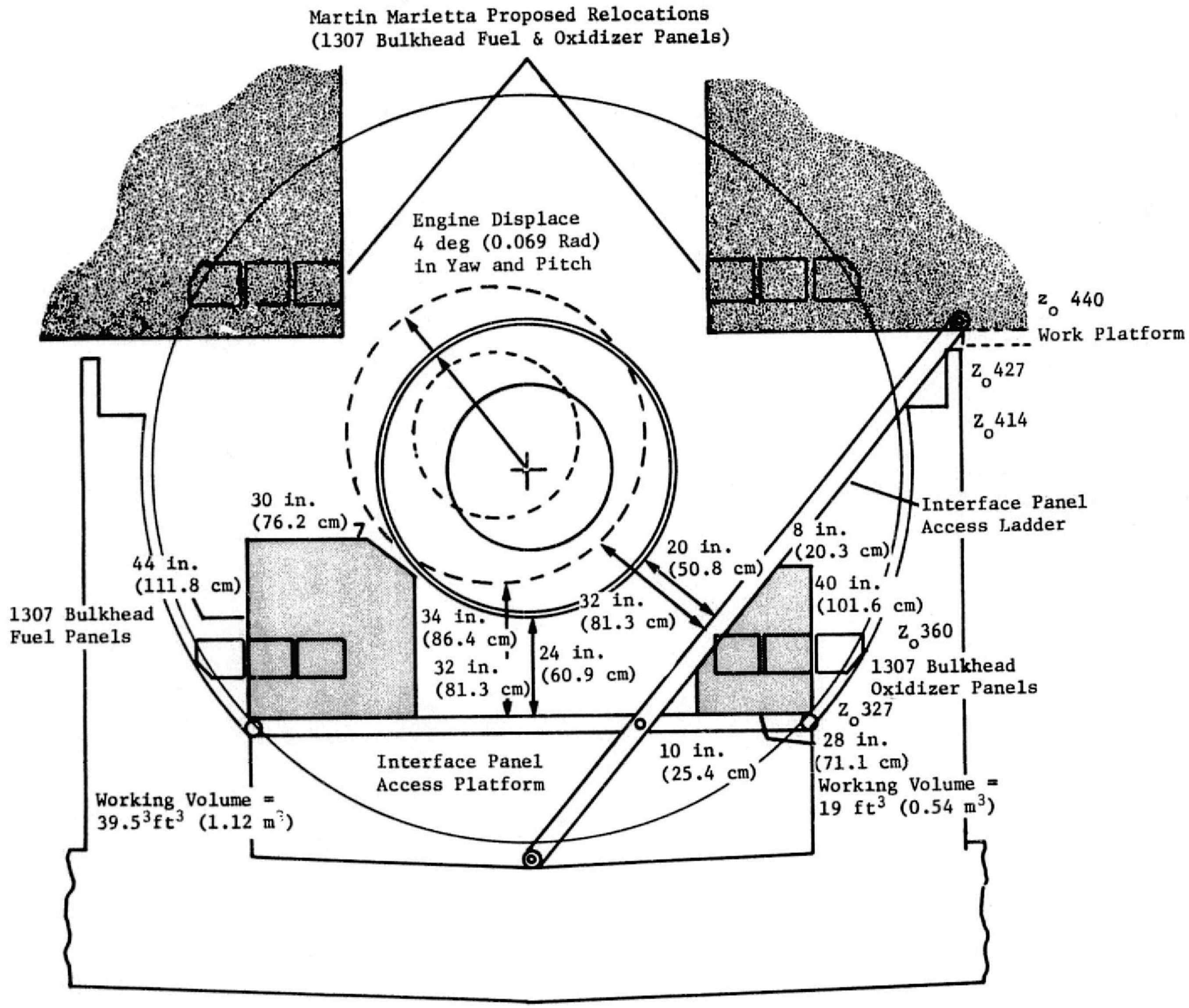


Figure III-F-6 Access Assessment - End View (Horizontal)

Figure III-F-6

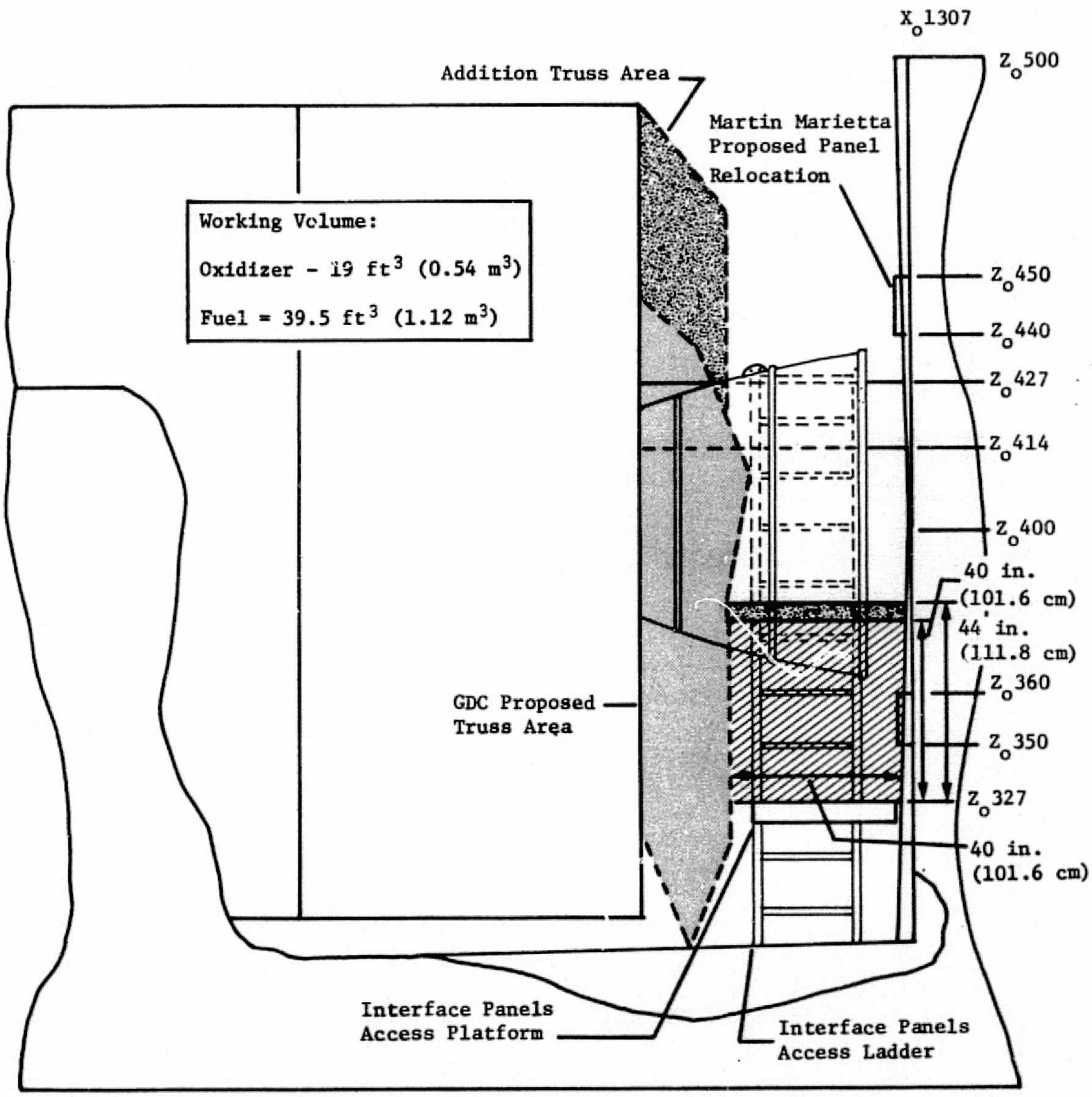


Figure III-F-7 Access Assessment Side View (Horizontal)

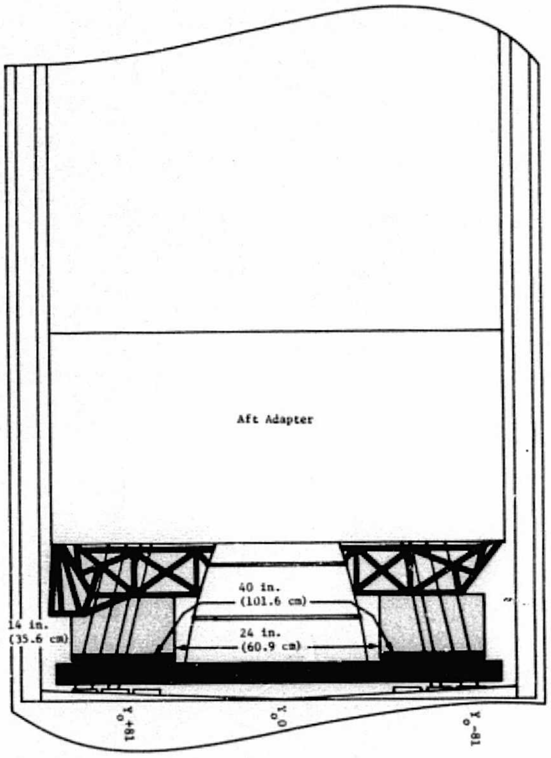


Figure III-F-8 Access Assessment Top View (Vertical)

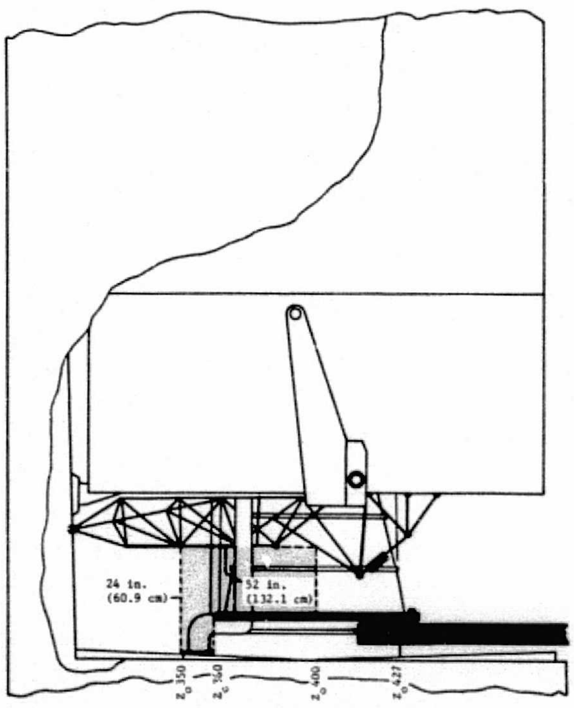


Figure III-F-9 Access Assessment Side View (Vertical)

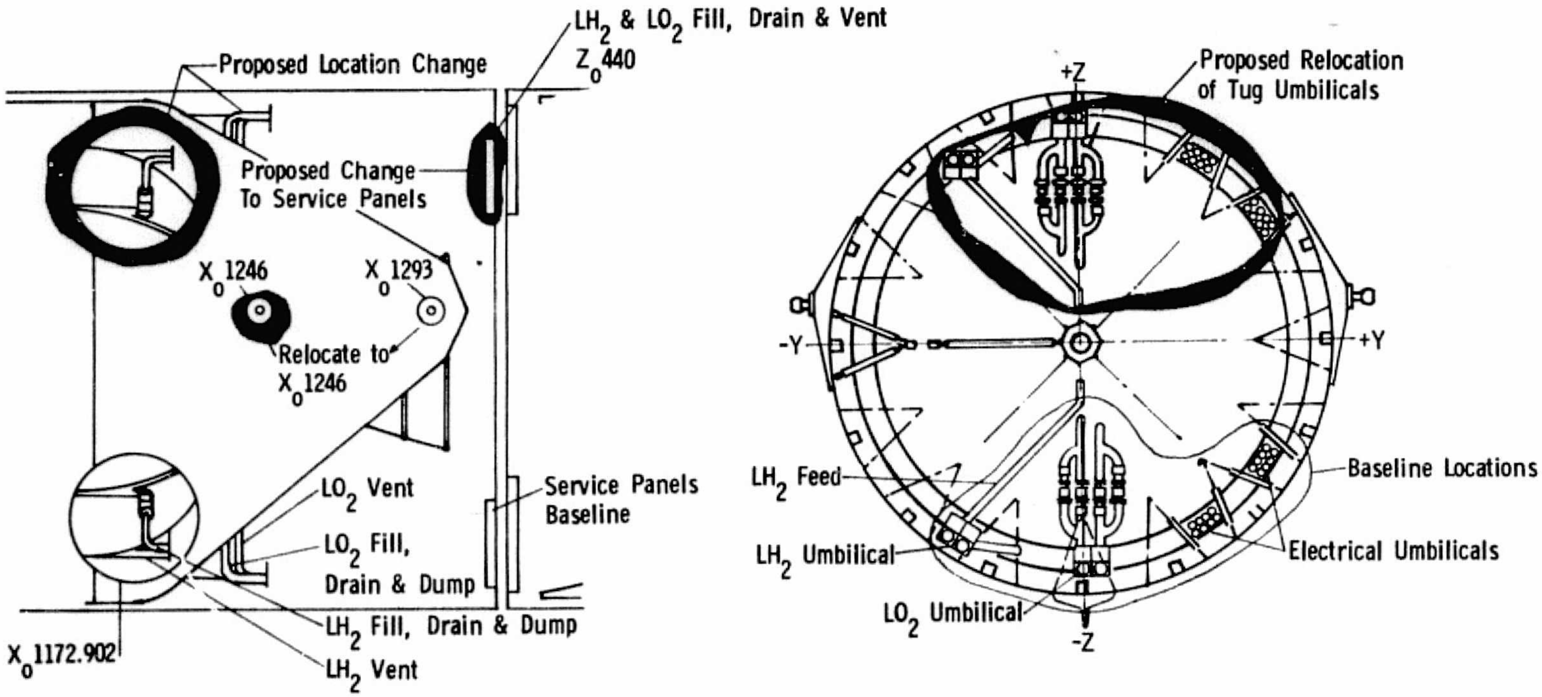


Figure III-F-10 Relocation of Tug Fuel, Oxidizer, and Electrical Umbilicals

Tug APS Propellant Loading Provisions - Several modifications are recommended for the Tug baseline system to improve and simplify checkout and servicing of the APS. These modifications are illustrated in Figure III-F-11, and are as follows: (1) a servicing port should be added between the series valves ahead of each thruster to provide for functional and leak check of each valve. This capability also provides an adequate means to purge the APS system and to decontaminate the system as required without contaminating the catalyst bed of the thruster; (2) addition of solenoid valves, a quick disconnect, and a cap are required for pressurant servicing of the He sphere and the N_2H_4 tanks to provide series isolation at the servicing connections, and the pressure regulator in the ground servicing fill connection should be deleted; and (3) addition of isolation valves are recommended between the helium storage tank and the pressure regulators to accommodate concurrent hydrazine and helium loading. During loading of the APS propellant tanks, helium will be applied to bottom the bladder in the tank, and then vented as the liquid displaces the helium gas during fill. The isolation valves allow loading of hydrazine and helium concurrently and also allow the flight pressurization of the APS propellant tanks to be delayed until late into the final countdown. The pressure rating of the APS helium sphere should be increased from 3000 psi (206.8×10^5 n/m^2) to 3200 psi (220.6×10^5 n/m^2). This change would allow both APS and MPS system to be loaded concurrently to the same pressure with a common pressurization system. This minimizes operations complexity and reduces cost by having only one Tug ground helium pressurization system.

3.1.2 Shuttle/Orbiter Design Impact - The following paragraphs define those areas of design concerns related to the Orbiter/payload accommodations, and they include consideration of functional capability and access impacting Tug ground operations.

3.1.2.1 C&W Monitoring and Functional Reaction Capabilities Related to Safing Activities - The current baseline definition associated with Orbiter processing of C&W data is rather vague; however, it should be recognized that certain parameters considered critical to the safety of the crew, Tug and Orbiter should have crew reaction capabilities. These measured parameters would primarily pertain to Tug conditions such as overpressures, critical temperature, and the existence of hazardous (toxic or explosive) vapors. The current Orbiter displays appear to be adequate as to indication of hazardous conditions, but inadequate as related to taking corrective action. Therefore, a need for greater override and manual control capability will be required on either the C&W panel or MSS console located in the Orbiter cabin. The following paragraphs will identify those areas where additional capability is required.

Figure III-F-25

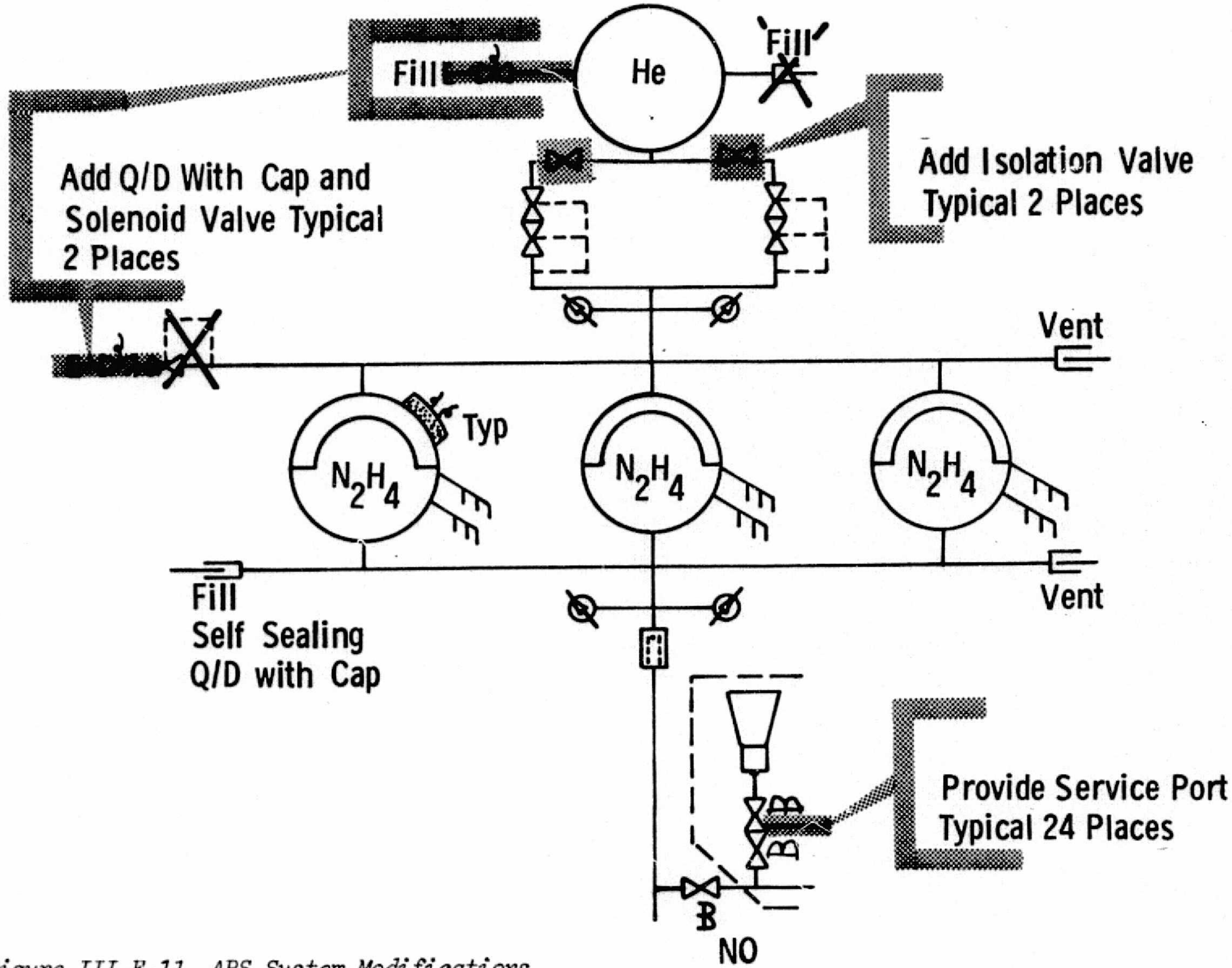


Figure III-F-11 APS System Modifications

1) LH_2 and LO_2 Temperature and Pressure Monitoring and Control - Monitor and control of main tank overpressures will provide the Orbiter crew an element of safety should a failure occur in the relief system. This monitor and control should also be available to the ground crew.

2) C&W Hazardous Vapor Display and Control Capabilities - Currently no provisions are made for display of the existence of hazardous vapor conditions in the payload bay. A requirement exists to determine if the payload bay is safe to enter during postlanding ground operations and, further, the existence of an explosive atmosphere in the payload bay could generate the need to abort the mission. Corrective action to relieve this condition will probably be procedural in nature, such as dumping the source of the hazardous vapor or, if in orbit with the Tug in the payload bay, merely opening the payload bay doors and allowing space vacuum to pump the vapor out. The various procedural options can be developed later in the program. However, the detection and alarm system must be considered during the development of the Orbiter or the Tug. The detection system should be developed within the Orbiter payload bay, but an alternative could be the use of vapor detectors already identified for the Tug system.

3.1.2.2 *Helium Venting of Tug/Payload* - Due to the degrading effects of helium on certain spacecraft and Tug hardware, it is recommended that all helium venting be dumped overboard from the Orbiter through one of the T-0 launch umbilicals.

3.1.2.3 *Tug/Payload Mating to Orbiter Access Provisions* - In conjunction with the required Tug changes discussed in paragraph 3.1.1.5, certain changes are also required for relocation of payload bay service panels. Figure III-F-12 illustrates the changes associated with the service panels.

3.1.2.4 *Propellant and Pressurant Loading Provisions* - In conjunction with the changes identified in paragraph 3.1.1.6, the following changes to the Shuttle/Orbiter will be required:

1) Fuel Cells Reactant Loading - This function requires loading of LH_2 and LO_2 reactants for the Tug fuel cells. Current payload accommodations documentation indicates a provision for GH_2 and GO_2 accumulator fill connections at the T-0 service panels. Provisions should be made to accommodate cryogenic handling for reactant tank filling, with appropriate control systems also being added to the interface. In addition, fuel cell vents should also be added to the T-0 fuel and oxidizer panel.

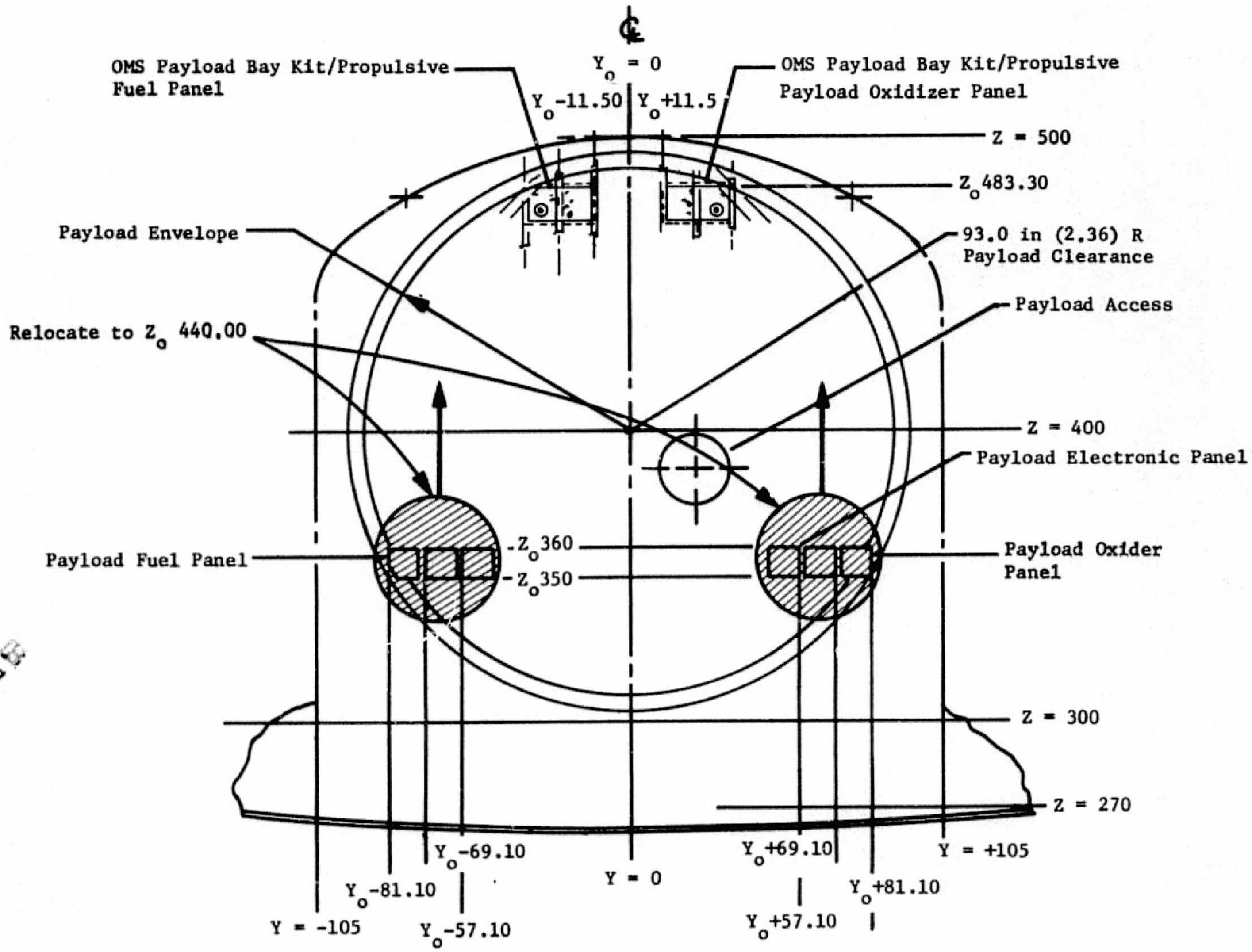


Figure III-F-12 Relocation of 1307 Service Panels

2) MLI Purge Vent Provisions - Figure III-F-13 provides an illustration of the currently proposed MLI purge system. During prelaunch, ambient helium from ground supply is used to purge the MLI. The helium is contained in a purge bag. The helium is supplied from Tug installation in the Orbiter until liftoff. At liftoff, the purge is terminated and the evacuation valves are opened to vent the insulation system. Upon Orbiter reentry, the purge bag is repressurized from the helium supply lcoated on the Tug adapter.

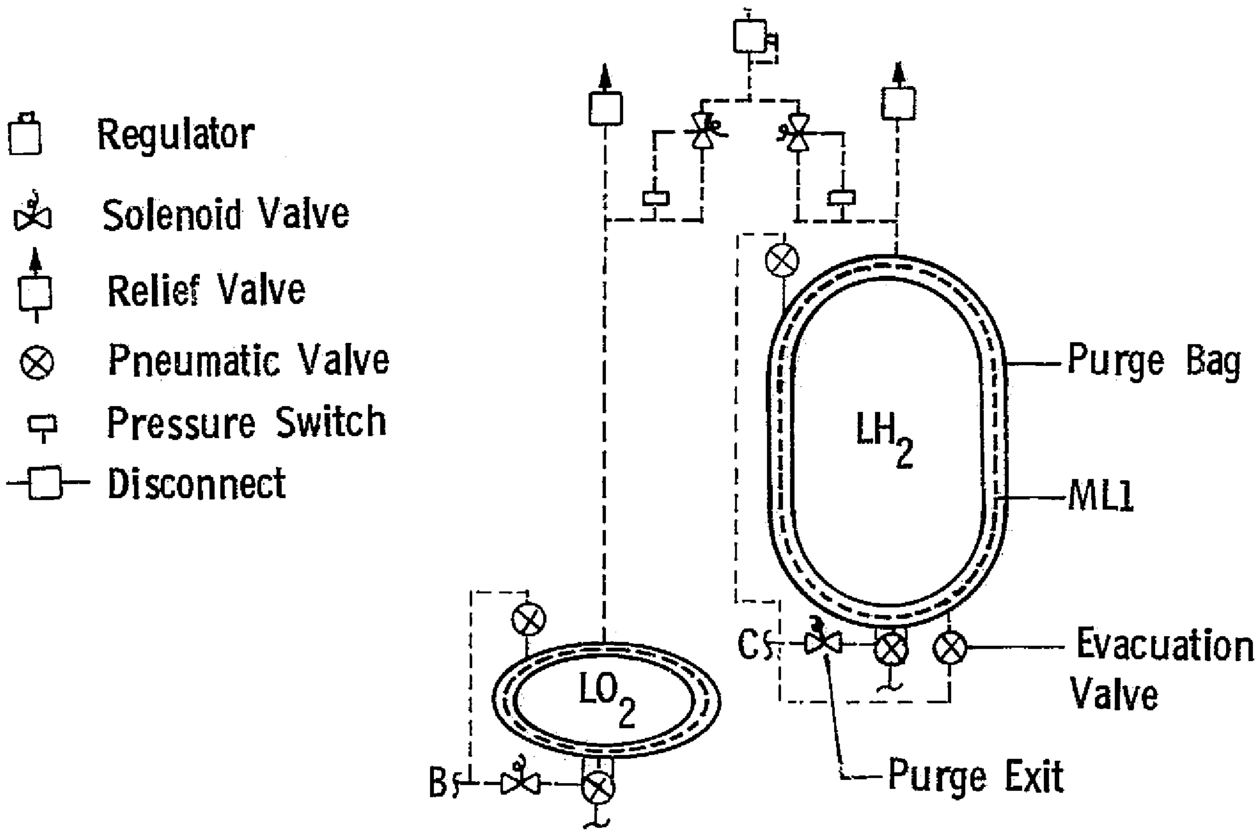


Figure III-F-13 MLI Purge Vent Provisions

Dedicated MLI purge vent should be added to the T-0 umbilical panels. The purge gas may contain propellant vapors due to stage leakage and, because of degrading quality of helium on certain hardware, should not be vented into the payload bay or the manifold helium vent. Venting into the manifold vent could cause a backpressure to be imposed on the purge bag. The bag, as has been currently defined, is capable of only low differential pressure, and the backpressure would require a higher purge bag supply pressure which may be incompatible with the purge bag capability. Figure III-F-14 illustrates the locations where these vents could be added to the T-0 panels.

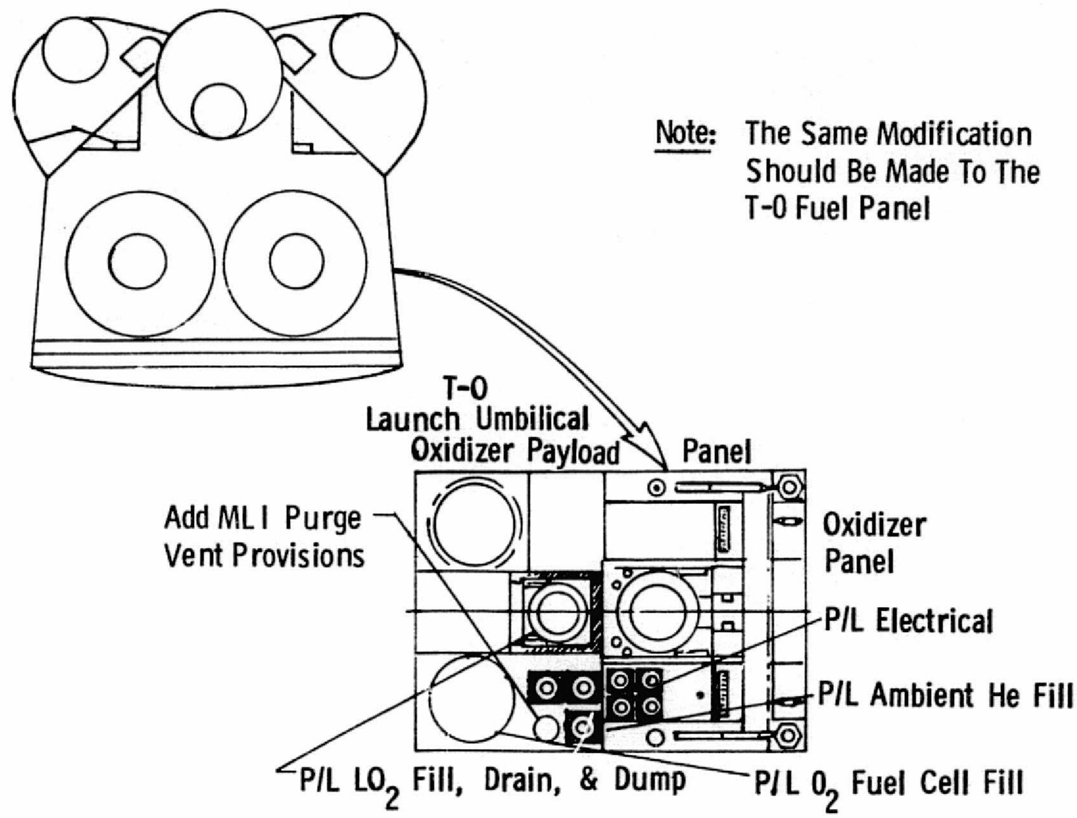


Figure III-F-14 T-0 Panels Modifications (MLI Purge)

3.2 Facility and GSE Requirements

These paragraphs contain those minimum design requirements associated with the Tug and Orbiter processing facilities (TPF & OPF), the launch pad facilities, and the various GSE items needed for processing, maintaining, and safing the Tug/payload during normal processing or contingency operations. Because the design definitions of the facilities and GSE are in an early conceptual phase, no capability exists to perform assessments of design adequacy on baseline configurations. Therefore, the subsequent paragraphs should be considered design requirements to supplement the requirements already contained in the facility and GSE Requirements Data Sheets of the appendixes associated with this study.

3.2.1 Tug Processing Facility Design Requirements - During review of the functions required for Tug processing in the TPF, the facility requirements data sheets were evaluated against functional requirements. This evaluation did not indicate any TPF facility requirements that were not already covered in the data sheets.

3.2.2 Orbiter Processing Facility Design Requirements - Same as paragraph 3.2.1.

3.2.3 GSE Design Requirements - The following paragraphs define design requirements for Tug peculiar GSE and supplement GSE requirements currently contained in Appendix B, or provides design requirements for new GSE identified during performance of the assessment.

3.2.3.1 Spacecraft Handling Equipment and Work Stands - Design of handling equipment and work stands should be in accordance with the safety requirements identified in paragraph 3.6.3 of this subplan. Design and fabrication shall be the responsibility of the spacecraft supplying agency.

3.2.3.2 Spacecraft Simulator Requirements - The baseline Tug processing flow identifies the requirement to verify the mechanical interface, capture, and latching mechanism when the Tug mission is assigned to service or retrieve an orbiting spacecraft. The verification will be accomplished using a spacecraft simulator. Due to the possibility of a large variety of spacecraft requiring this service, it may be impossible to develop a universal simulator that would assure interface compatiblity. Therefore, it shall be the responsibility of the spacecraft agency to provide the required simulator. The simulator shall be designed and fabricated in accordance with the safety requirement defined in paragraph 3.6.3 of this subplan.

3.2.3.3 Ground Checkout RF Requirements to Support Tug/Payload Processing - During the ground processing of the Tug/payload, a requirement exists to establish and verify RF communications between the various elements of the Space Transportation System. This requirement encompasses communication between the Tug, Orbiter, spacecraft, and their respective ground control stations. This communications verification will be accomplished via an RF system between the TPF and the various ground stations, which will execute commands to the affected element and have command responses verified via an RF open loop. Tug/payload-to-Orbiter communications will have to be established in a similar manner, and will include all normal mission communications routines with commands and responses being verified.

To accomplish this verification, a parasitic antenna system will be required at the TPF, OPF, SPF, PCR, and the various elements control stations. Figure III-F-15 illustrates the antenna system concept that will be required. The system will be used for all RF communication verifications, with the exception of those classified spacecraft carried on the Space Tug System. Problems associated with classified communications are discussed in paragraph 4 of this subplan.

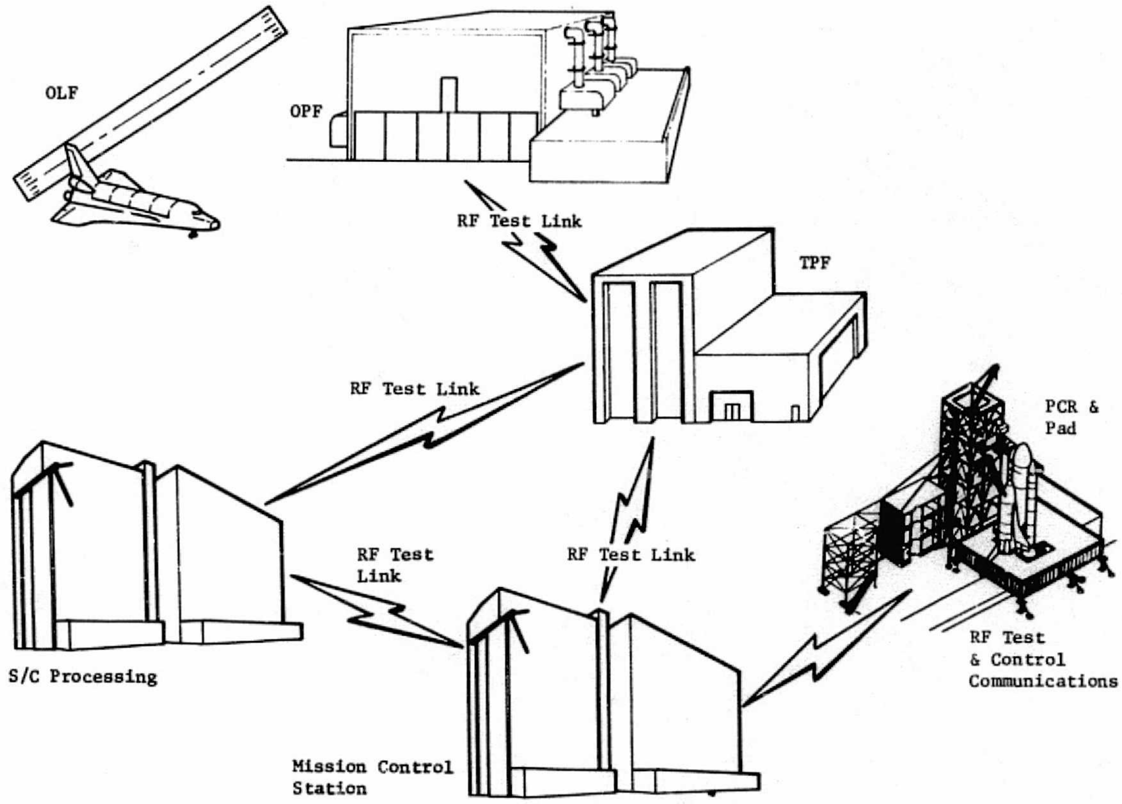


Figure III-F-15 RF Ground Antenna Test System

3.2.3.4 *APS Servicing Unit Requirements* - In conjunction with the change related to Tug APS system defined in paragraph 3.1.1.6, the following requirements are established for the APS servicing unit:

1) Provide isolated helium pressure source-to-gas side of tank bladder.

2) Provide evacuation capability for fuel side of tank bladder.

3) Provide N_2H_4 loading capability while regulating helium back pressure.

4) Accomplish N_2H_4 loading at a rate of 3 gpm (0.011 m^3pm).

5) N_2H_4 self-contained storage capacity of 100 gallons (0.379 m^3).

Figure III-F-16 provides a conceptual design for the APS Servicing Unit.

3.2.4 Launch Pad Facility Design Requirements - The following paragraphs define design requirements for launch pad facilities to support Tug Ground Operations. These requirements are intended to supplement those already contained in Appendix C.

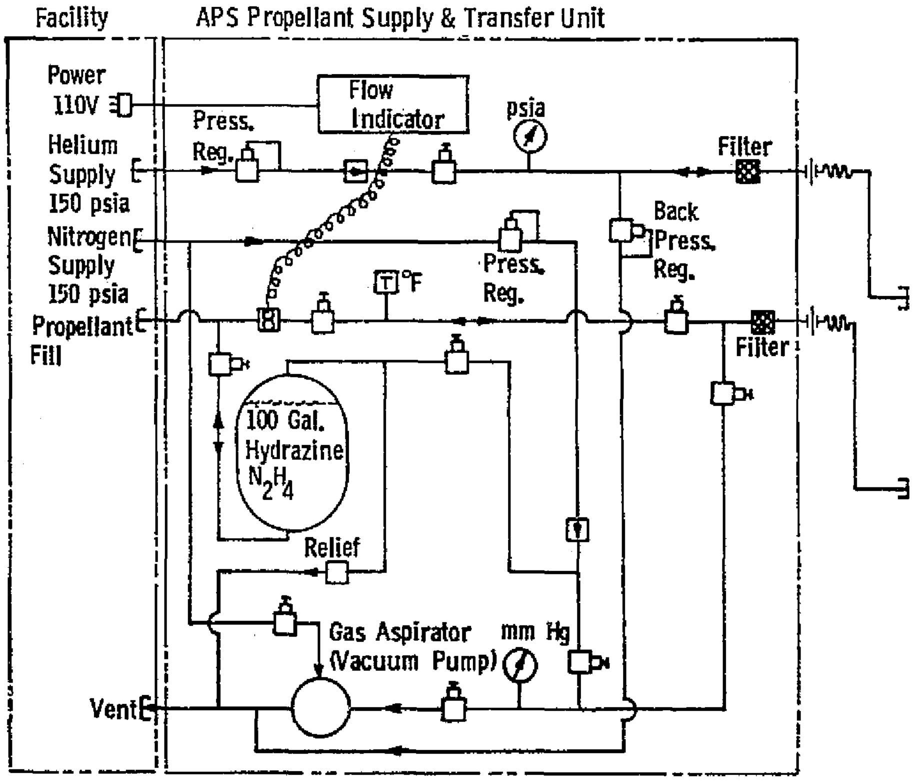


Figure III-F-16 APS Servicing Unit

Propellant and Pressurant Loading Provisions - During evaluation of propellant and pressurant loading functions and in conjunction with recommended Tug and Orbiter changes defined in paragraphs 3.1.1 and 3.1.2, the following paragraph outlines change or capabilities that should be considered for the launch pad facilities.

Common Tug/Orbiter Fuel Cell Loading Provisions - Figure III-F-17 illustrates changes to the Orbiter fuel cell LH_2 loading facilities that will enable the system to provide Tug LH_2 fuel cell reactant loading. Corresponding changes should also be accomplished on the LO_2 fuel cell reactant loading system.

3.3 Transportation Requirements

These paragraphs contain the minimum design requirements generated by transportation activities associated with the Tug/payload, Orbiter/Shuttle and the necessary transporation equipment to support the transportation activities. Consideration was given to simplification of these activities during this assessment. Detailed rationale for the selection of various transportation modes for which this assessment was accomplished is contained in paragraph 3.3 of subplans A, B, and C. Generally, the following assumptions are made for accomplishment of this assessment based on decisions and recommendations contained in the referenced paragraph.

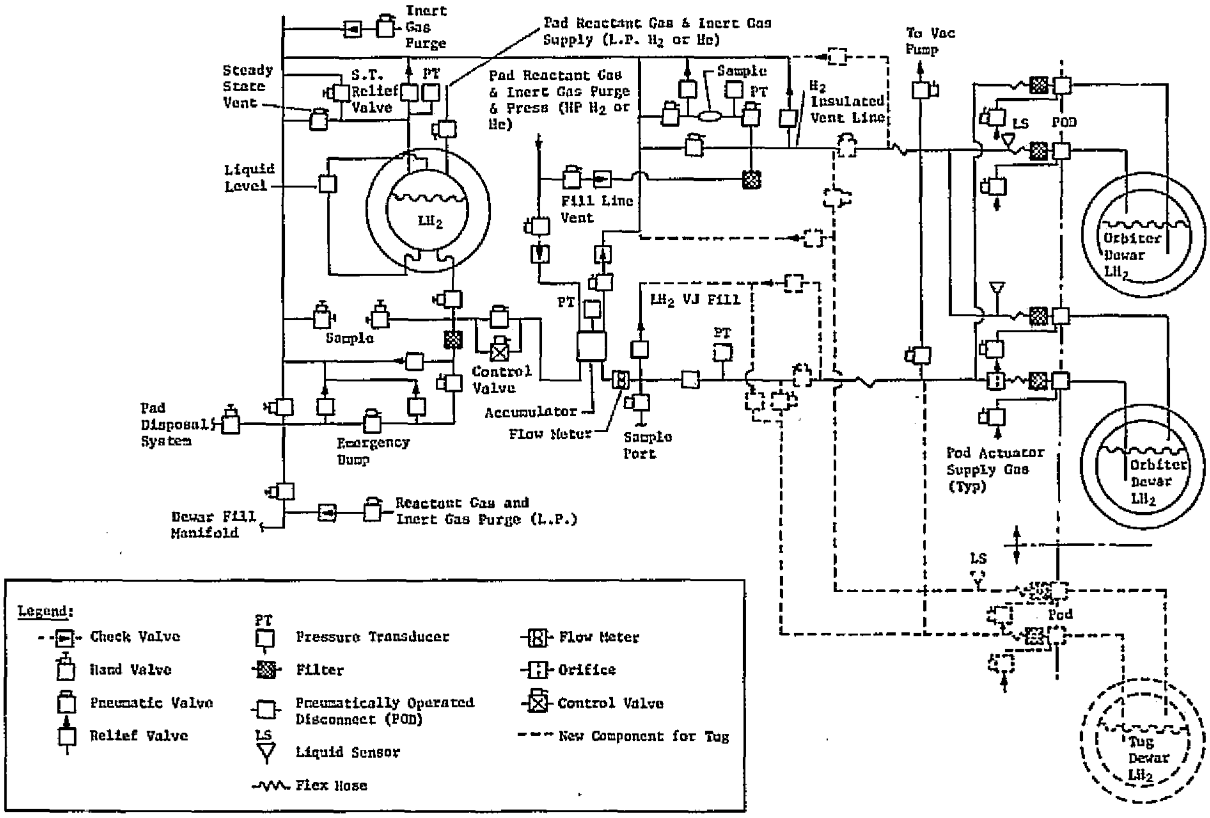


Figure III-F-17 Fuel Cell LH_2 Loading System

1) Tug Transportation Between KSC and WTR - This transportation function will be accomplished using the multi-use cargo canister in the piggyback mode on the B-747 aircraft. (Refer to paragraph 3.3.2, subplan A.)

2) Tug Transportation from Manufacturer to KSC - This transportation function will be accomplished using the multi-use cargo canister in the piggyback mode on the B-747 aircraft. (Refer to paragraph 3.3.3, subplan A.)

3) Normal Ground Movement at KSC - (Refer to paragraph 3.3.4, subplan A.)

   a) Postflight ground transport of the Tug from the OPF to the TPF will be accomplished by a ground transporter which is classified as GSE and the requirements are located in Appendix B.

   b) Spacecraft transporters for use at KSC are classified as GSE and the requirements are located in Appendix B.

   c) The manipulator and various handling equipment using the the transportation functions are classified as GSE and the requirements are contained in Appendix B.

   d) Post-Tug/payload processing transportation functions will be accomplished using the multi-use cargo canister in the ground configuration and in a vertical orientation.

3.3.1 Tug Design Requirements - No special design features other than those identified in the baseline configuration documents and paragraph 3.1.1. The special handling provisions recommendations of paragraph 3.1.1.1 will be needed to support Tug/payload transportation activities.

3.3.2 Shuttle/Orbiter Design Requirements - Review of normal and contingency modes of transportation functions related to the Tug operations have not generated any requirements that would impact the design of the Orbiter/Shuttle.

3.3.3 TSE Design Requirements - The following paragraphs define those features that need to be included in the identified TSE to support the Tug transportation requirements. Inasmuch as the TSE has not yet achieved a conceptual baseline design status, the following statements should be considered as minimum design requirements peculiar to transportation of the Tug.

3.3.3.1 Multi-Use Cargo Canister - The piggyback B-747 Multi-Use Cargo Canister has been recommended as the preferred mode of transportation for the Tug/spacecraft and kick stage. The supporting rationale for these recommendation are contained in Section 3.3 of subplans A and B. Based on this decision, certain minimum design requirements peculiar to the Tug become apparent. These cargo canister design requirements are specified in the following paragraphs.

1) Tug/Payload Mounting Provisions - The following design requirements should be considered and integrated into design of internal mounting provisions of the multi-use cargo canister.

a) Tug Mounting Provisions - The cargo canister should be designed for maximum integrated payload length, width, and height which is, essentially, the baseline configuration of the Orbiter Payload Bay (Figure III-F-18). Therefore, the most desirable Tug mounting provisions would be those currently identified in JSC 07700, Volume XIV, using a vernier bridge bolt-down fitting and the standard Orbiter payload bay longerons and fuselage frames. Figure III-F-19, illustrates the fundamental configuration and location of the Tug transportation retention system.

b) Spacecraft and Kick Stage Mounting Provisions - Whenever the Tug/payload cannot be transported in an integrated configuration due to vertical orientation requirements imposed by the spacecraft then special mounting/retention mechanisms will have to be supplied by the spacecraft agency that would be compatible with the universal retention system of the multi-use cargo canister. Figure III-F-20, provides a conceptual approach to solution of this problem. A similar approach could be used when kick stages were transported in an unintegrated configuration.

2) Environmental Design Requirements - The following environmental design considerations must also be integrated in the design of the multi-use cargo canister. These environmental design requirements are considered worst case allowables at the interface between the Tug/payload and the cargo canister as we understand them at the present time. It should be recognized that, as the various designs progress and further analysis is completed, these worst case limits may improve. However, the primary environmental design considerations should always provide minimum levels at the interface points.

a) Temperature - The internal temperature of the multi-use cargo canister should be controllable in a worst case condition to a range from 45°F (7.0°C) to 122°F (50.0°C), during ground and air transport modes of operation.

b) Humidity - During ground and air transport modes of operation, the internal humidity of the multi-use cargo canister should be controllable in a worst case condition to maintain a relative humidity of equal to or less than 50% within the temperature range identified previously.

c) Cleanliness - The multi-use cargo canister must have the capability of establishing and maintaining a 100,000 class clean environment.

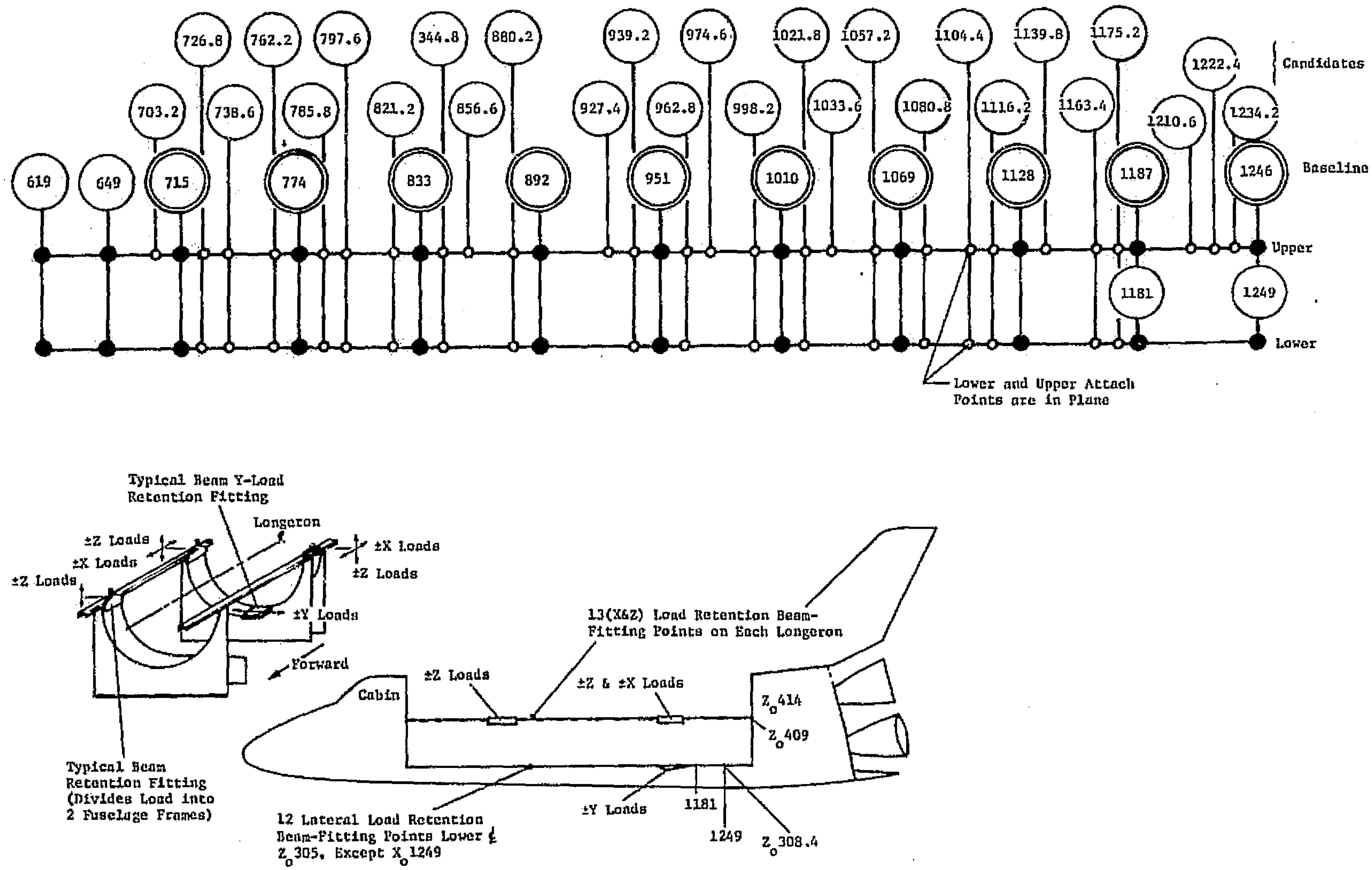


Figure III-F-18 Orbiter Payload Bay Configuration

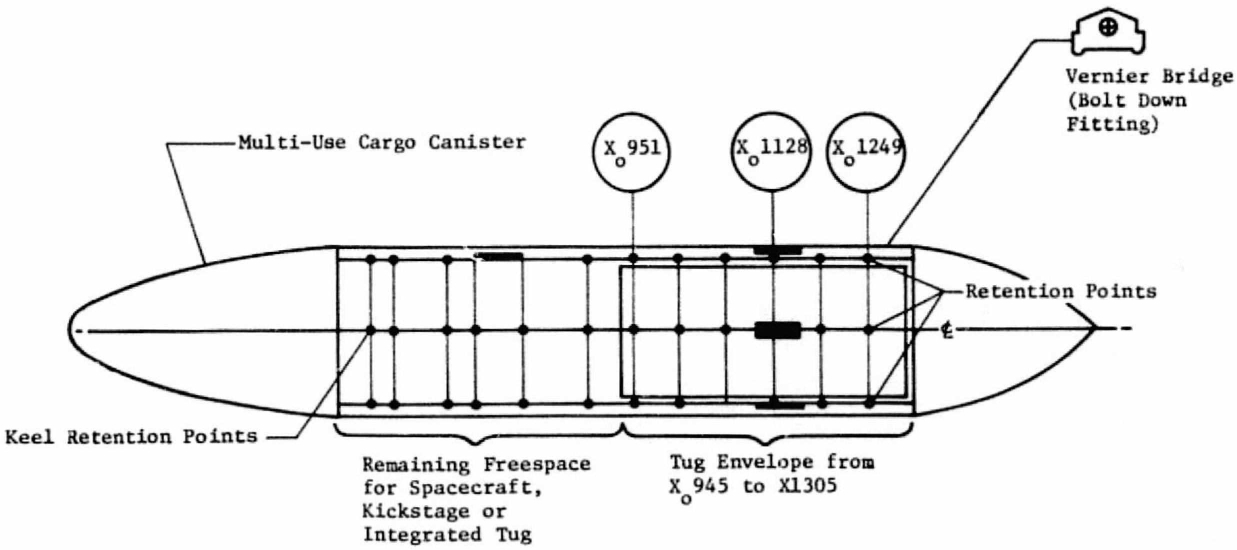


Figure III-F-19 Tug Transportation Retention System

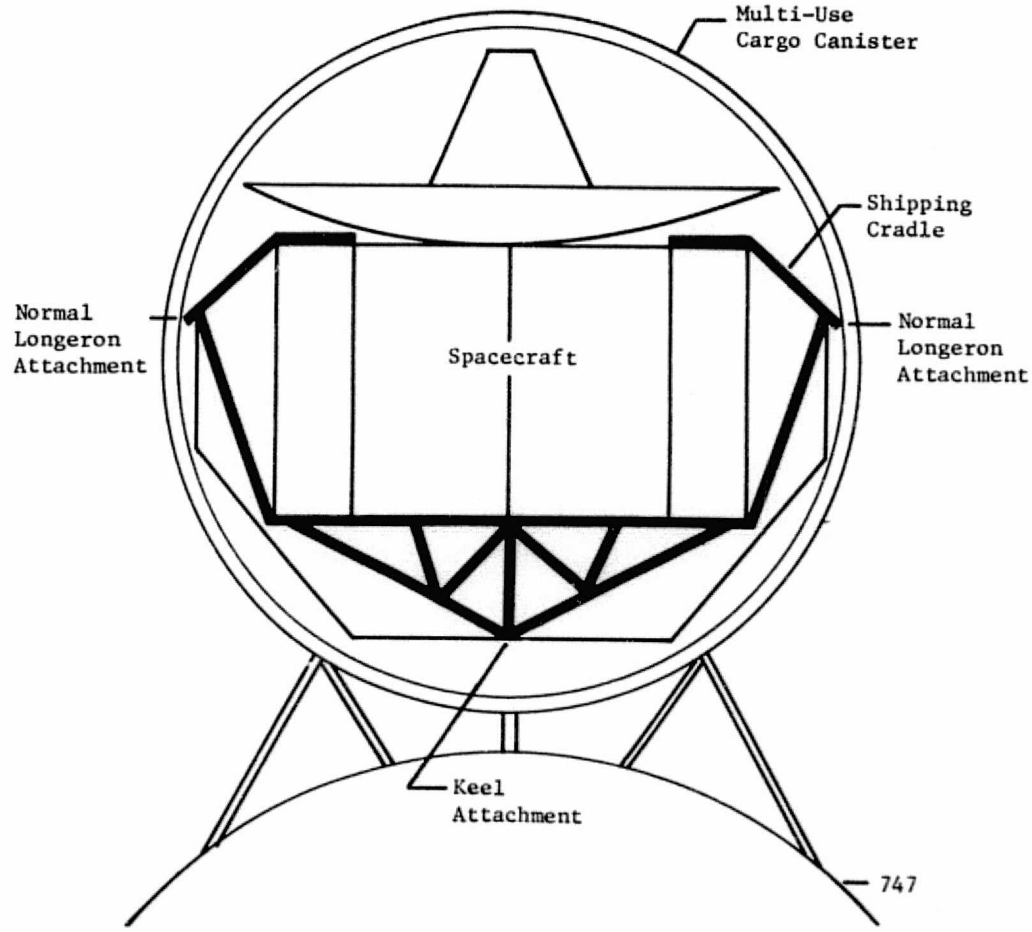


Figure III-F-20 Spacecraft/Kick Stage Retention Concept

d) <u>Shock</u> - Internal interface shock shall not exceed a 2-g peak, half sine in a frequency range of 3 to 5 Hz.

e) <u>Vibration</u> - The worst case allowable vibration at the multi-use cargo canister internal interface shall not exceed the following sinusoidal motions (Figure III-F-21):

2 to 5 Hz @ 1.0 in. DA

5 to 25 Hz @ 1.3-g peak

25 to 50 Hz @ 0.036 in. DA

50 to 1000 Hz @ 5-g peak

at a sweep rate no slower than 1/2 octave/minute.

3) <u>Other Design Requirements</u> - The multi-use cargo canister should also have the capability to perform the following functions:

a) Provide internal pressurization and venting during take-off and landing of the B-747 Aircraft.

b) Provide continuous shock and vibration monitoring/recording capability at the cargo canister to Tug/spacecraft and kick stage interfaces.

c) Provide interface capability to monitor and record Tug/spacecraft and kick stage critical vibration, shock, pressure, and temperature measurements.

d) Provide strap-on capability for an RTG water evaporative thermal control system.

e) Provide continuous 28 Vdc to the Tug/payload buses. Two isolated ground and power systems will be required to satisfy any Tug or spacecraft TEMPEST requirements.

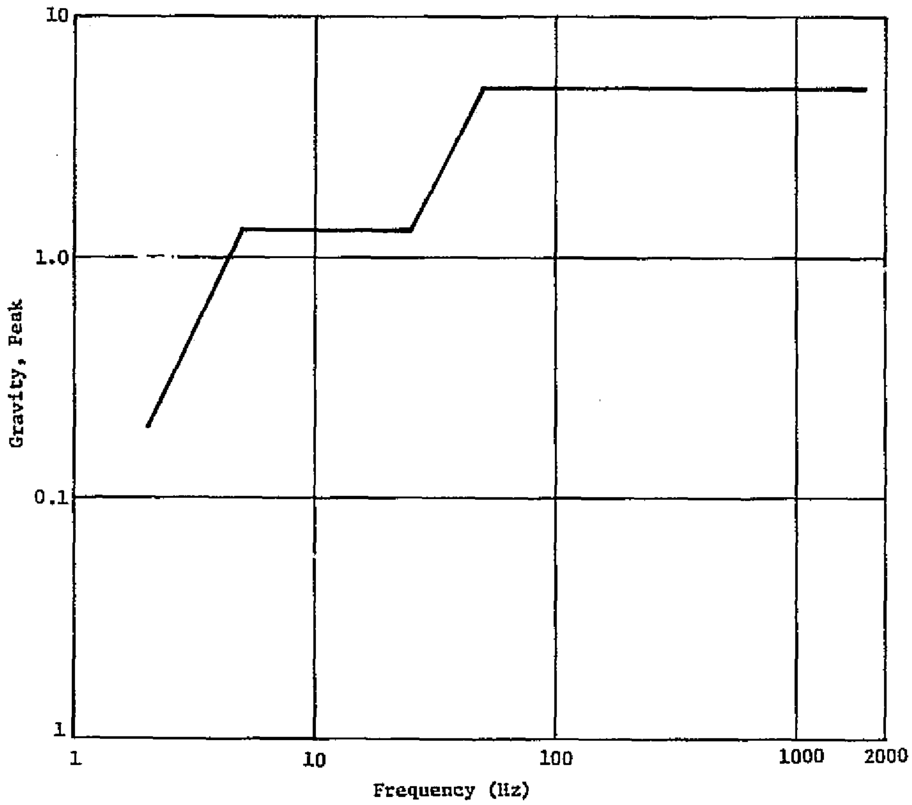


Figure III-F-21 Sinusoidal Vibration Requirements

3.4 Operational Data Requirements

These paragraphs contain the minimum flight operational instrumentation and caution and warning requirements for the Tug/payload to provide adequate data for support of maintenance activities and assurance of safe operations. The assessment was performed using both Tug and Orbiter baseline data as well as various other contractors' data to establish the recommended minimum OFI and C&W requirements. The following paragraph defines these areas of concern where additional OFI, C&W, and control capabilities should be considered. The fundamental approach used to perform this assessment was to consider the minimum flight data required to support the "last flight is best test" concept. The assessment also included an analysis of contingent hazardous conditions that should be displayed and a definition of control capability requirements.

3.4.1 Tug Design Impact - The following paragraphs identify area of design impact for the Tug, related to operational flight data and caution/warning monitoring and control capability. These areas consider use of OFI and C&W status and reaction during both ground and flight operations as well as instrumentation requirements during transportation functions.

3.4.1.1 *Tug OFI Requirements* - The current Tug baseline configuration definition contained in MSFC 68M00039-2 provides an inherent capability within the data management, measurement, and computer subsystems to provide data that will support a condition-monitoring maintenance technqique as well as given adequate contingency/hazardous conditions indications. Table III-F-1 provides an estimate of the minimum numbers and types of measurements that should be made. This tabulation provides for both C&W hardware and flight operations monitoring capability. As the design of the Tug and Orbiter mature these measurements will have to be reviewed and updated as required. The only problem that becomes apparent at this early date is associated with C&W response capability. The present philosophy related with C&W capabilities seems to be one that, if no obvious reaction to a hazardous condition exists, then ignore it. It is our opinion that this approach early in the design phase could cause serious cost and redesign problems during the operational phase. Where response inadequacies existed in certain C&W-monitored conditions, design recommendations were made in either paragraph 3.1.1 or 3.1.2.

3.4.1.2 *Transportation Data/Instrumentation Requirements* - During the transportation operations of the Tug from the manufacturer, WTR, ETR, or a contingency site certain data instrumentation will be required. These readings include shock, vibration, temperature, and pressure. Shock and vibration monitoring will measure dynamic loads imposed by handling and air transport (primarily at the attachment points); temperature and pressure measurements will establish the integrity on the tanks and temperature sensitive devices during transportation functions. Because these measurements are also required during normal ground and flight operations their requirements should be integrated with normal OFI requirements wherever possible.

3.4.2 Shuttle/Orbiter Design Impact - During performance of this assessment the defined operational data requirements identified in Table III-F-1 indicated only selected reaction capabilities needed to be added to the Orbiter side of the interface, these changes are defined in paragraph 3.1.2.

3.5 Manpower Staffing

Not applicable to this subplan.

3.6 Safety Requirements/Constraints

These paragraphs identify in general the safety considerations that must be included as an input to design activities during the development phase of the Tug program.

Table III-F-1 OFI Requirements Matrix

System-Subsystem \ OFI Sensor Type	Temperature	Pressure	Vibration	Shock	On-board Checkout	Flow	Position	Voltage	Liquid Level	Depletion L-L	Hydrogen Leak	Oxygen Leak	Residual Gas Analysis	Contamination	Speed RPM	Current Signature	Totals
Structures	8	4	9	8							2	2	2	4			39
Forward Skirt			3	3													6
Main Skirt			3	3							2	2	2				12
Liquid Hydrogen Tank	4	2												2			8
Liquid Oxygen Tank	4	2												2			8
Aft Adapter			3	2													5
Propulsion	8	35	2		26	6	32	7	8	4					4	76	208
Main Engine	3	6	2				3								2		16
Feed-Fill-Drain-Vent LH	1				1		7	2								8	19
Feed-Fill-Drain-Vent LO	1				1		5	2								6	15
Pressurization		6					8									13	27
Hydraulic						2	4	1	2						2	1	12
Propellant Load-Measure								2	6	4							12
APS	3	23			24	4	5									48	107
Thermal Control	66	8			5	5	6		2						1	8	101
Active T/C	12	2			5	3	3		2						1	3	31
Passive T/C	30																30
Insulation-Purge	24	6				2	3									5	40
Avionics	8				922		10	24	4	2	1	1		2			974
Nav.-Guid.-Control					240												240
Data Management					256												256
Communications					69												69
Measurements					229												229
Electrical Power Distr.	8				128		10	24	4	2	1	1		2			180
Totals	90	47	11	8	953	11	48	31	14	6	3	3	2	6	5	84	1322

Provisions to accommodate safe Tug ground operations must be considered during the design phase of the Tug, Shuttle/Orbiter, and GSE/facilities. The inherently hazardous operations associated with Tug processing are identified in Task 1 (subplan A) and included vehicle handling, propellant/cryogenic transfers, pressurization and electrical power supply operations. The basic safety requirements to accommodate these operations are defined in paragraph 3.2.6.1 of Baseline Space Tug Requirements and Guidelines, MSFC 68M00039-1. Application of these requirements, and the additional requirements identified below, will permit procedural control of hazardous operations.

3.6.1 Tug Design Requirements - The Baseline Space Tug Requirements and Guidelines provides for monitor and control of Tug safety critical functions by the Orbiter while in or near the Orbiter (Refer to MSFC 68M00039-1 para 3.2.6.1.2.V.). This requirement should be extended to include the capability for monitor and control of safety critical conditions by ground support equipment during Tug processing.

3.6.2 Shuttle/Orbiter Design Requirements - MSFC 68M00039-1 provides for purge provisions to neutralize propellant leaks during and after propellant servicing and after Orbiter landing (Refer to MSFC 68M00039-1, paragraph 3.2.6.1.3(5).). This requirement is satisfied by the Orbiter payload bay purge system as defined in Space Shuttle System Payload Accommodation, JSC-07700, Volume XIV. An additional requirement should be imposed on the Shuttle/Orbiter system to provide hazardous vapor detection of the payload bay purge exhaust.

3.6.3 Facility/GSE Design Requirements - The following additions/revisions to MSFC 68M00039-1 are recommended.

3.6.3.1 Safety Factors - The following safety factors will be applicable to ground support structural, mechanical, and fluid system design as minimum values.

1) General structure

    a) Yield factor of safety - 2.00

    b) Ultimate factor of safety - 4.00

2) Pressure vessels, valves, fittings, transfer piping, fill and vent lines, hoses, etc.

    a) Proof pressure - 1.50 times design limit pressure

    b) Yield pressure - 2.00 times design limit pressure

    c) Burst pressure - 4.00 times design limit pressure

3) Hoists and slings

a) Poof load - 2.00 times static load

b) Design ultimate load - 5.00 times static load

3.6.3.2 *MSFC 68M00039-1* - Para 3.2.6.1.3.b(1) states "Tug lift/hoist mechanisms shall be designed to be fail operational/fail safe." It is recommended that control systems will be designed to be fail operational/fail safe. Mechanical components will be fail safe or provide a factor of safety of five times static load.

3.6.3.3 *GSE* - Ground handling units, work stands, ladders, and similar items will provide a safety factor of 2.0 from overturning under the most adverse combinations of applicable loads, including wind loads.

3.6.3.4 *Pressurization/Leak Check Facilities* - Facilities for conducting pressurization or leak check operations will provide separation or blast attenuation barriers to ensure peak overpressure is less than 1.0 psi (6895 n/m^2 at the next nearest work station.

3.6.3.5 *Handling/Transfer Facilities* - Facilities intended for handling/transfer of hazardous commodities will provide hazard detection and warning systems.

3.7 Fleet Utilization

Not applicable to this subplan.

3.8 Site Activation

Not applicable to this subplan.

3.9 Ground Checkout Software

During the Tug acquisition phase there are a number of operational software constraints that must be considered to reduce operational problems. Generally, these problems are the software constraints on hardware and hardware impacts on software. In addition, no amount of analysis, care of system design, and attention to details will preclude errors, misconstructions and inexactnesses due to timing, system prerequisites, hardware constraints, and human errors. However, these problems can be reduced by proper use of appropriate checkout, debug, verification, and validation techniques and the employment of a hardware stimulation that is of relatively high fidelity when compared to the Tug/payload system.

3.9.1 Software Constraints on Hardware - Normally software will conform to hardware requirements; however, it is possible that software may dictate how many interface lines are required between the spacecraft and the Tug, and between the spacecraft and the Orbiter. Therefore, before baselining the interface hardware, a detailed analysis needs to be accomplished over the wide range of the known spacecraft to determine a practical envelope of Tug or Orbiter services that are to be offered to the spacecraft. Also, if a fixed interface is baselined, there may be limited access that would correspondingly limit software and hardware operations, and assessment of the situation should be accomplished early in the Tug development phase.

3.9.2 Hardware Impacts on Software - The previous paragraph illustrated one type of hardware limitation on software; other hardware impacts on software are real-time operations, increased numbers of operations required per second, and timing. Prerequisities and interlocks are hardware requirements that impact software.

The previous paragraph deals with the various problems that impact software development, and identifies the need for certain types of studies that are required to be accomplished early in the acquisition phase. In summary these studies/tasks are as follows:

1) Determine the configuration and requirements of the hardware required for validation.

2) Examination of ground versus airborne controls for safing, processing, and monitoring.

3) Establishment of systems engineering and management methods of handling and integrating the software of many diverse spacecraft requirements.

The first task (validation hardware) would involve determination of location, makeup, Orbiter hardware,required use, contingencies, short and long term support, spacecraft contractor involvement, customer administration, configuration control, flexibility, adaptability, multiple developments, cost, acquisition, activation, acceptance at site, and validation procedures.

The second task would evaluate ground software versus airborne software for common elements, or combined elements with ground operations. Airborne flight philosophy could be modified to accommodate ground operations resulting in an overall savings of dedicated software operations.

The third task would be to identify and attempt to integrate a wide variety of spacecraft requirements into a viable and common set of software modules. Emphasis needs to be directed towards understanding what details, procedures, validation hardware availability, spacecraft hardware availability, early (factory needs) demands and GSE (HIMs) changes will do to the software production, integration, and validation process for a large number of spacecraft.

The preceding paragraphs have presented the general areas of concern that are applicable to all activities related to ground checkout software. Inasmuch as these software modules have not yet been developed, an assessment of functional or design adequacy cannot be accomplished. Therefore, each function contained on the processing requirements flow (Figures III-F-2 through III-F-3) was compared to the software modules identified in Appendix D to assure that provisions had been made for each activity required to process the Tug from postlanding through launch. This assessment concluded that module identification was adequate when the general considerations identified previously are factored in the requirement sheets.

3.10 Maintenance Requirements

The maintenance concept currently planned for the Space Tug program as defined in paragraph 4.6 of task 3.0 - IUS and Tug Fleet Utilization Subplan B and paragraph 3.10 of task 1.0 - Space Tug Operational Subplan A, dictates the necessity for early implementation and performance of logistics support requirements analysis. The elements yielded during this analysis that are of paramount importance to the preliminary design activities are detailed identification of maintenance tasks, facility interfaces, flight hardware electrical and mechanical interfaces, reparable/non-reparable status, hardware predicted life, MTBF, and MTBR. These defined hardware characteristics, coupled with preliminary mechanical installation design, will be the primary source for determination of design adequacy related to maintenance requirements. However, before generation of these analyses and preliminary designs, certain other characteristics must be considered, such as accessibility, maintainability, and mission life requirements. Other considerations that should be kept in view during preliminary mechanical installation design are avionics alignment requirements and a palletized concept to group LRUs with common functions for ease of maintenance. The primary area of design concern that can be addressed at this early date is maintainability; paragraph 3.10.3 provides a detailed discussion of these requirements and they should be included in any future procurement documents issued for Space Tug hardware. Other items having design impact that are related to maintenance activities deal primarily with access problems and are defined in the following paragraphs.

3.10.1 Tug Design Impact - During performance of this assessment and the special emphasis study on access provisions before launch, certain access problems related to performance of scheduled and unscheduled maintenance have become apparent. The following paragraphs identify these problems and provide possible solutions for each.

During access evaluation it was necessary to accomplish a preliminary LRU identification. This was completed during performance of task 2.0 and the results are located in Table 2.1.5-1 of addendum 3 and Table 5-1 of Appendix E, contained in the Tug Fleet and Ground Operations Schedules and Controls Study Final Report. These LRU identifications form the baseline for the following access discussions.

3.10.1.1 Inadequate Access to LH_2 Horizontal Dump Valve and LH_2 Fill, Drain and Prevalve - The current Space Tug baseline configuration document MSFC 68M00039-2, identifies these valves as being located inside the LH_2 tank. The present state of art design associated with this type of valve has created a capability to operate adequately while submerged in LH_2. However, this type of application has generally been employed in single shot systems. Therefore, any life or reliability data associated with these valves would be at best suspect, and would require extensive testing to qualify the valves to the anticipated Tug life and environmental requirements.

Therefore, it would seem reasonable to assume that before the 20-mission life span currently assigned to Tug expires, and the requirement for the valve to operate satisfactorily over a temperature range from approximately 120°F (48.8°C) to -420°F (-251.1°C), that there is a relatively high probability that the valves will degrade, if not totally fail, during this period.

Figure III-F-22 illustrates the current location of these valves, and highlights the access problem associated with their removal and replacement.

Given that the above assumption that the valves will degrade or fail during the expected life of the Tug, then several possible options become available for solution of the access problem. The options available are as follows:

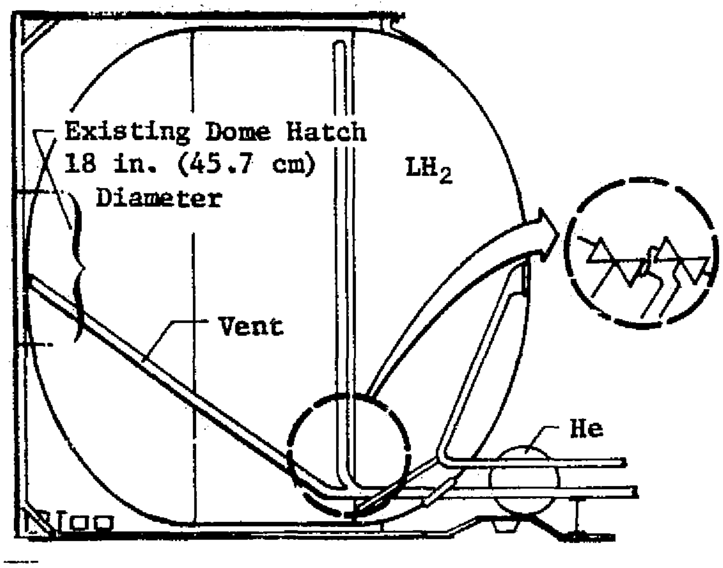


Figure III-F-22 Submerged Valves Location

Access Problem Definition

Only access to internal portion of LH_2 tank is through an 18-in. (45.7 cm) dia Hatch on the forward end of tank. Hatch diameter is considered marginal for personnel entry. Futher, any activity related to GSE installation would jeopardize the integrity of the MLI and purge bag because of limited work area.

1) If present access provisions are to be retained, the hatch size should be increased to a minimum of 24 inches (61 cm) and provisions made to protect the MLI and purge bag.

2) To improve access to the subject valves, a hatch could be added to the LH_2 aft dome. From a structural standpoint this concept would dictate placement of the hatch in the sump region of the aft dome, which would create a different type of access problem due to the minimum clearance between the LH_2 and LO_2 tanks of 10 inches (25.4 cm). Because of this condition, if an aft hatch is to be considered, extensive structural and stress analysis must be performed to assess the design requirements associated with locating the hatch along the arc of the aft dome in the approximate region of x_o 1082. Current design capabilities are such that a location such as this is feasible. In addition to this change the subject valves should also be palletized with simplified clamp connections to provide ease of maintenance during removal and replacement activities.

3) The third and most desirable option would be to mount these valves external to the LH_2 tank in the intertank region of the Tug, with only feeder lines penetrating the tank. This approach would not only provide adequate access but would also eliminate the inherent heat loads associated with control functions, and would improve valve reliability by removing them from the hostile thermal environment of being submerged in LH_2. It should also be noted that the same access problem exists with relation to the LH_2 vertical and horizontal vent valves, and the preceding recommendation should also be considered in the case of these valves.

3.10.1.2 <u>Inadequate Access for Removal of APS Hydrazine Spheres</u> - Space Tug baseline configuration document describes the N_2H_4 fuel spheres to be approximately 32 inches (81.3 cm) in diameter with an elastomer bladder. Past experience would indicate that the corrosive nature of hydrazine will degrade the bladder to a point where replacement is required long before the Tug life of 20 missions has expired. This condition would impose a periodic requirement to remove and replace the hydrazine spheres. The access doors in the intertank region as presently defined are 30 inches (76.2 cm) by 30 inches (76.2 cm) which is not compatible with the size of the hydrazine spheres.

Figure III-F-23 illustrates the defined location of the hydrazine spheres and highlights the access problem associated with their removal and replacement.

Several options are available that will alleviate this problem and improve overall access to the hydrazine and helium spheres as well as the avionics hardware located in the intertank region. However, each of these options will require a configuration change to the baseline Tug. These options are as follows:

1) The first option that will provide adequate access for removal and replacement of the APS hydrazine sphere would be to implement the optional field splice at station x_o 1061.74

   If implemented, this solution would require special separation features to be added to the TPF checkout cells to support the aft skirt and intertank skirt during removal and replacement activities; further, provisions for accomplishing the separation such as quick disconnect (Marmom clamp or Zeus fasteners) will have to be added to the field splice. Even though this technique would provide adequate access there would probably be a serious weight and processing time penalty.

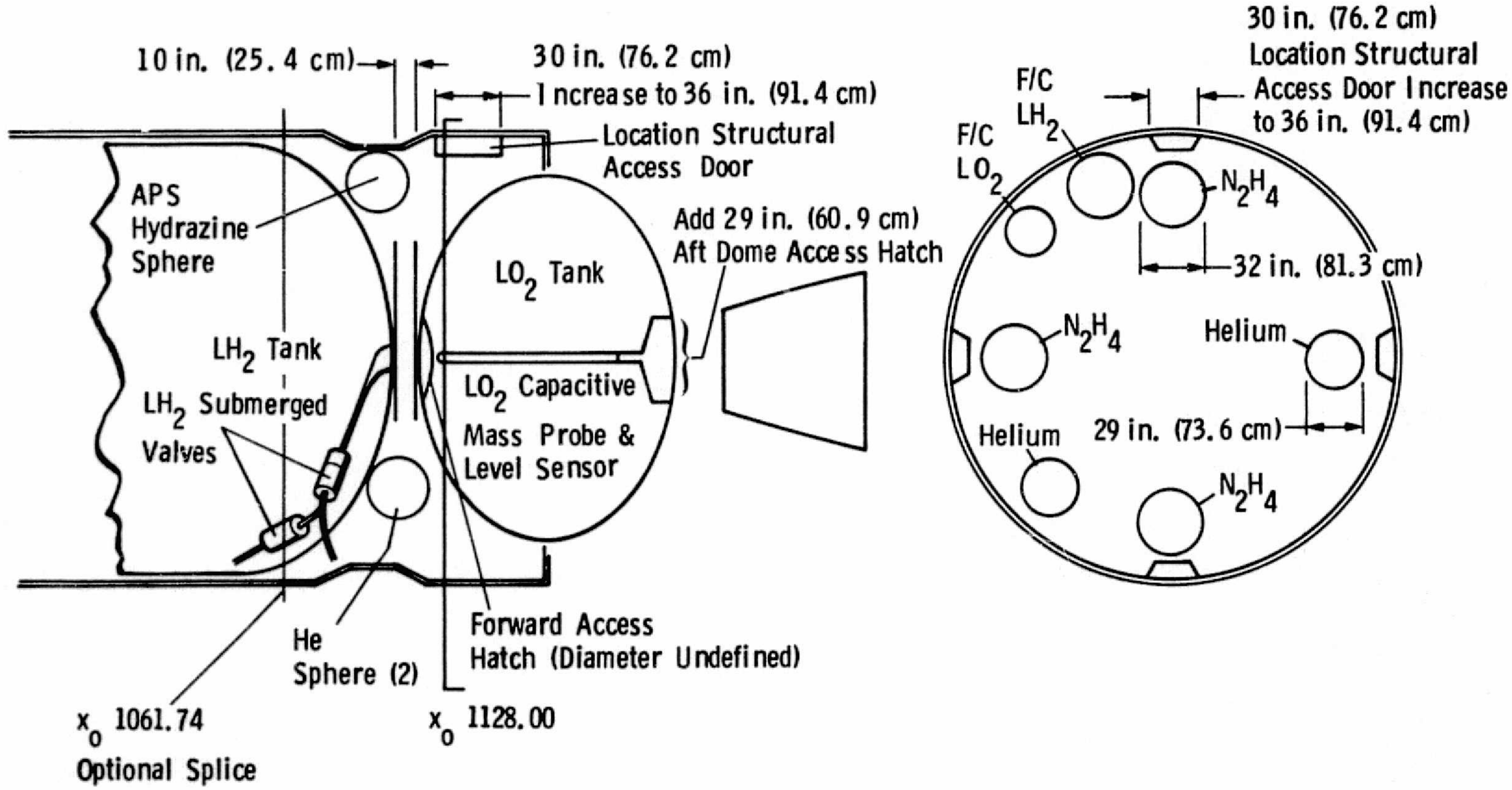


Figure III-F-23 Intertank Hardware Locations

2) The second option would be to increase the structural opening for the APS motor assembly from 30 inches (76.2 cm) by 30 inches (76.2 cm) to 36 inches (91.4 cm) by 36 inches (91.4 cm) and make the APS hydrazine spheres and helium spheres an integral part of the assembly (Figure III-F-24). The change would also provide adequate access for the intertank helium spheres which, at best, have marginal access due to their 29 inch (73.7 cm) diameter.

3) The third option would involve increasing the size of the external intertank access panel from the presently defined configuration of 30 inches (76.2 cm) by 30 inches (76.2 cm) to 36 inches (91.4 cm) by 36 inches (91.4 cm). This would probably be the simplest and most economical change that can be accomplished. However, option 2 presents an attractive approach to accomplish a modular or palletized concept for subsystems and LRUs.

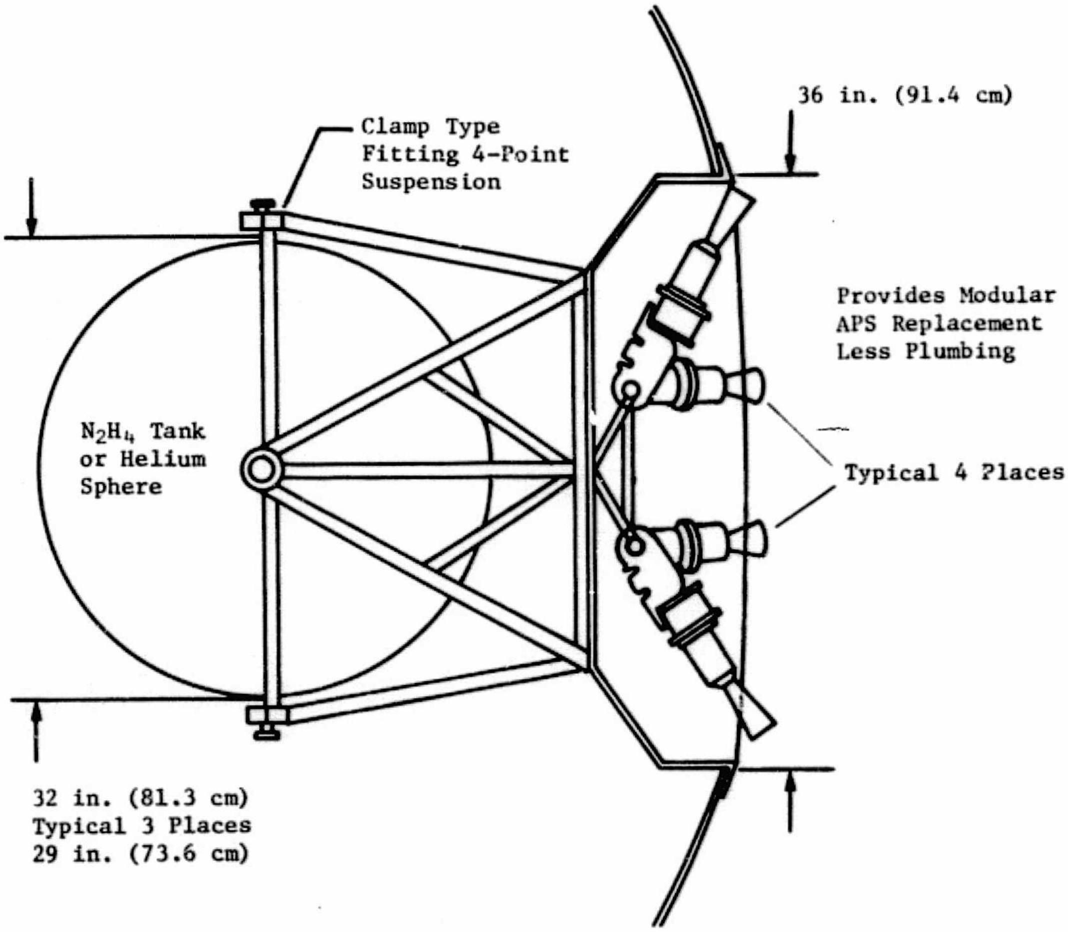


Figure III-F-24
N_2H_4 Tank and Helium Tank Access and Mounting Modification

3.10.1.3 Inadequate Access for Removal of the LO_2 Capacitive Mass Probe and Level Sensors - Current Tug baseline configuration documentaton MSFC 68M00039-2, identifies that the only access available for removal and replacement of LO_2 mass probe or level sensors will be the forward dome access hatch of the LO_2 tank. It must be noted that the current configuration shows only a 10-inch (25.4 cm) clearance between the LH_2 and LO_2 tanks, which means no access exists. The probability of a failure in this hardware is less likely than the aforementioned cases; however, these measurements are critical to the loading operations and flight performance. Therefore, provisions must be made to enable access in the event of a failure. Figure III-F-23 illustrates the location and highlights the access problem.

Possible solutions to this access problem would include implementation of the optional field splice x_o 1061.74 discussed above or addition of redundant probes and sensors. Neither of these solutions totally solve the problems as indicated in the preceding access provision discussions. However, the addition of an access hatch in the LO_2 tank aft dome sump region would provide adequate access with a minimum of disassembly involved. To reach the dome would, however, require removal of the main engine. This would appear on the surface to be a major operation, but when the fact that the engine refurbishment requirement and relatively short life factors are considered it becomes apparent that engine removal will be performed every second or third flight. If the engine changeout does occur at this frequency, then scheduled probe and sensor removal, replacement, calibration, and refurbishment could be accomplished concurrently with engine maintenance. Further, the technology required for placement of the access hatch in the aft dome has already been accomplished on other tank systems such as the Saturn vehicles and, therefore, appears to be the most reasonable and practical solution for this problem.

3.10.2 Shuttle/Orbiter Design Impact - During performance of this assessment no access problems were identified with respect to the Shuttle/Orbiter payload accommodations that are directly related to Tug/payload maintenance activities.

3.10.3 Maintainability Considerations - Maintainability provisions must be established in Tug design to assure that:

1) Maintenance requirements are minimized by focusing design attention on those areas with greatest potential for support cost reduction.

2) Necessary preventive and corrective maintenance can be performed in turnaround time constraints.

3) Maintenance and maintenance support requirements are at the lowest possible cost level.

4) Maintenance and logistic support requirements make maximum use of existing facilities, equipment, and supply support items.

5) Maintenance and support requirements are technically and cost compatible with overall Shuttle program requirements.

6) Introduction of required maintainability provisions does not significantly increase Tug development costs and costs per flight or penalize vehicle weight and performance.

The Tug maintainability program should consist of three major elements as represented in Figure III-F-25. The first element is the establishment of maintainability design criteria that consist of quantitative and qualitative design requirements. The criteria must be established in design criteria documentation to discipline the design of the Tug so it can be easily maintained with minimum logistic support. Before development of the maintainability design criteria, Maintainability Significant Items (MSIs) are determined within the overall Tug program hardware by assignment of an MSI index number of criticality ranking, which represents a total score against a series of mission/cost impact factors. Typical elements in the series would include probability of mission failure should the hardware item fail, anticipated failure rates, criticality, failure detection time impact to the mission, LRU replacement time, and time/cycle sensitivity of the item. The ranking is used in conjunction with FMEA and safety hazard analysis to assign quantitative allocations, i.e., mean time to replace or repair, and qualitative allocations such as accessibility and ease of replacement to the MSIs.

The second program element is one of design assessment and analysis to evaluate Tug design and formulate the necessary trades and corrective action. The analysis process must progressively evaluate the Tug system and equipment designs and verify compliance with the maintainability criteria. As design problems are identified, recommended solutions will be developed and directed to the appropriate design agencies for resolution. Tug and support equipment design must be continually evaluated for maintainability application. When subcontractors are identified, hardware evaluation checklists and maintainability criteria must be performed to reach optimum maintainability decisions. Problematic areas and proposed resolutions should be documented for presentation at design reviews.

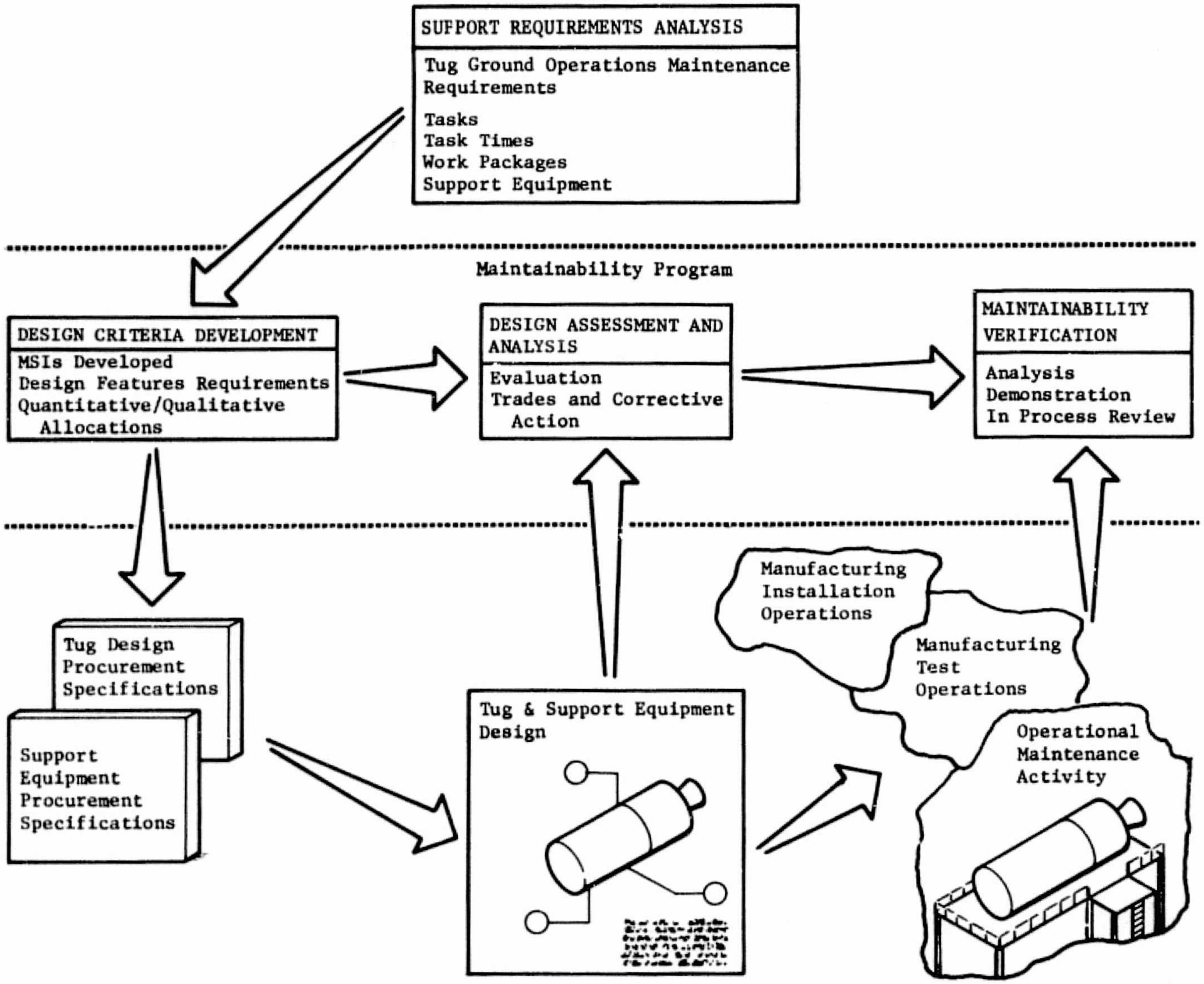


Figure III-F-25 Maintainability Implementation Methods

The third program element is the maintainability verification process to ensure design incorporation through further analysis, demonstration, and in-process review. Hardware compliance with maintainability requirements must be verified by observing the installation of hardware during the manufacturing process and performance of early operational phase maintenance tasks. Operations data including failure reports, maintenance records, and manufacturing test reports must be reviewed and improvement recommendations provided as required.

The maintainability tasks must be scheduled to support Tug program milestones and to provide early resolution to problems affecting launch turnaround capability, adverse repair times, and program cost.

3.11 Configuration Management

Not applicable to this subplan.

3.12 Timeline Funding

Not applicable to this subplan.

4.0 Special Design Studies and Results

4.1 General

This section of the subplan is devoted to evaluation of design concepts and requirements not necessarily related directly to the ground operational flows or functions, but which can have a major impact on the efficiency of Tug operations.

For example, although many references have been made to classified payloads, neither the Tug baseline configuration data nor the Shuttle/Orbiter preliminary design data addresses TEMPEST design and test requirements which will have a major impact on the STS program.

Much conversation is made regarding contingency operations, but very little planning for recovery from these conditions are being considered in early design definition activities. In the case of the Space Tug, major emphasis should be placed on ease of maintenance, replacement of hardware which could preclude an aborted launch, and modular design for simplification of test and checkout.

Most of these concerns can be grouped into two design categories, (1) modular design concept, and (2) TEMPEST design requirements.

4.2 *Modular Design Concept*

4.2.1 General - The modular design concept is one of grouping hardware into removable pallets or modules and can be accomplished at most any level of assembly. In the case of the Space Tug the highest level of modular design would most probably be the development of a propulsion module and a avionics module, whereas the lowest level of modular design could be the component level such as a set of reference gyros and associated electronics. The primary advantage to the modular approach would be the simplification of fault isolation and shortened replacement and reverification times. Another reason that this approach is attractive is that in the event of a subsystem failure late in the countdown, the simplified checkout could feasibly allow replacement of the module at the launch site and preclude the necessity of recycling the entire Tug and Spacecraft through their respective processing facility.

4.2.2 Space Tug Approach to Modular Design - The existing baseline configuration definition is mature enough to formulate some conceptual modules. The following paragraphs will define these potential modules starting at the system level and working through the subsystem/component levels including any new interface requirements that are identified.

4.2.1.1 Propulsion Module - The propulsion module as visualized under this design concept would be as illustrated in Figure III-F-26, and includes the following hardware:

1) Main and aft skirts
2) LH_2 and LO_2 MPS tanks
3) Main engine and APS
4) Propellant feed system
5) Pressurization and vent system
6) Active thermal control system
7) Fill and drain system
8) Fuel cell system
9) Hydraulic system
10) Selected interface, measurement and control hardware.

This configuration would allow for concurrent processing involving most of the hazardous operations at the same time as avionic processing that could be accomplished in a different location.

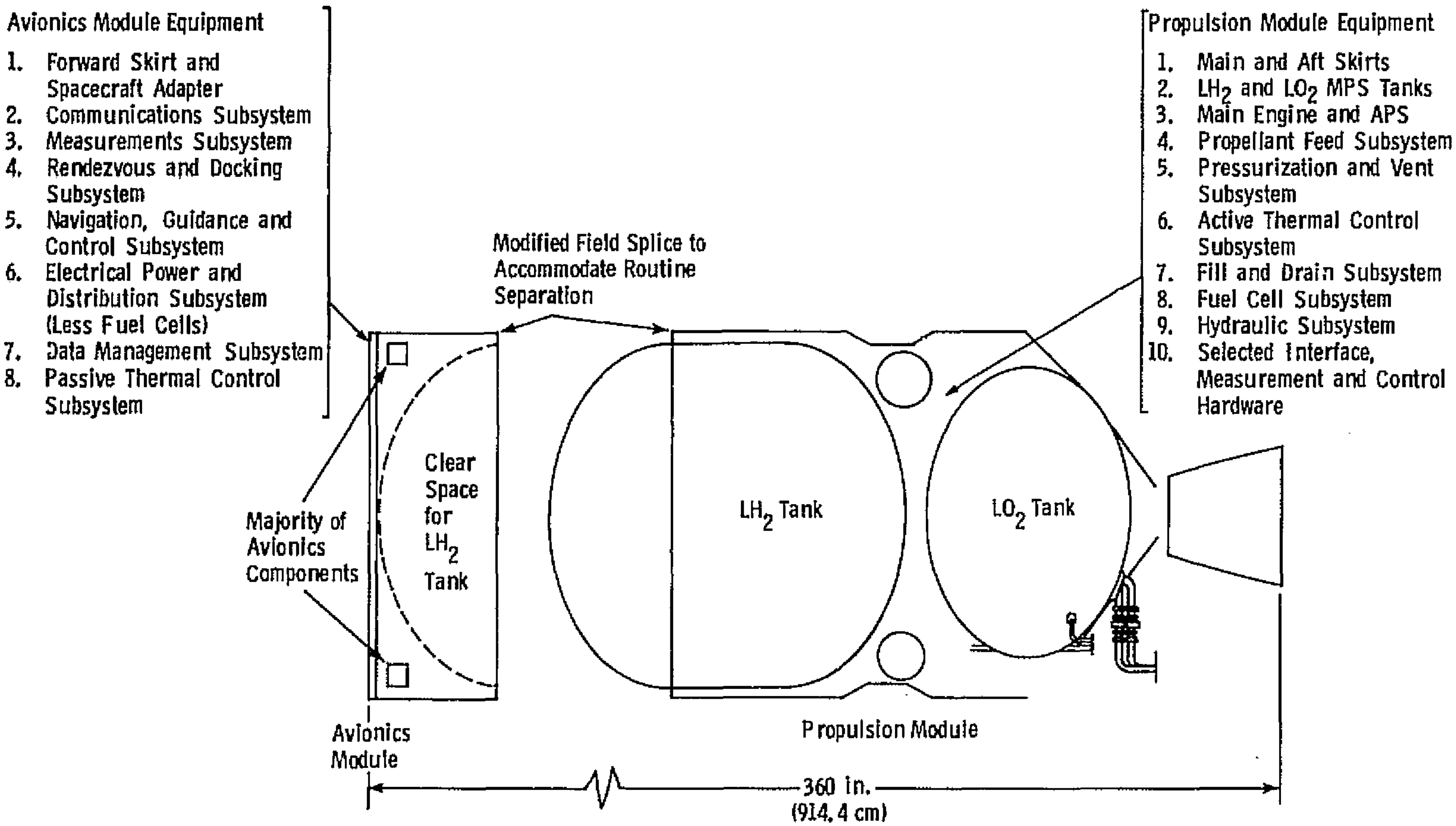


Figure III-F-26 Propulsion and Avionics Module Concepts

Figure III-F-26

4.2.1.2 Avionics Module - The avionics module as visualized under this concept would be as illustrated in Figure III-F-26, and includes the following hardware:

1) Forward skirt and spacecraft adapter

2) Communications subsystem

3) Measurements subsystem

4) Rendezvous and docking subsystem

5) Navigation, guidance, and control subsystem

6) Electrical power and distribution subsystem (less fuel cells)

7) Data management subsystem

8) Passive thermal control subsystem.

This configuration improves access to the various electronic LRUs, and simplifies avionics alignment operations.

4.2.1.3 Additional Modular Designs - After establishment of the propulsion and avionics modular configurations a detailed analysis will need to be performed to evaluate the feasibility of modularizing or palletizing lower indentures of hardware. Further, assessments of impacts on spares quantity and acquisition cost, facility/laboratory capabilities, skills requirements and turnaround time will have to be accomplished. Another area that must be investigated is the impact on overall fleet size, because it is conceivable that this approach will reduce the numbers of propulsion or avionics modules required to support the current traffic models.

Desirability of the modular design approach should be subjected to an in-depth study before initiating the detailed Tug design activities. The study would include a definition of a modular baseline configuration from the propulsion and avionics modules down through the lowest practical level of assembly. It would also include an updating of all the previous study activities such as functional ground operations, GSE and facility requirements, software requirements, skills and manpower, as well as timelines and fleet sizing.

4.3 TEMPEST Design Requirements

As indicated in paragraph 4.1 little information was contained in the Tug and Orbiter baseline definitions beyond the fact that there will be classified payloads. It must be recognized

even at this early date that whenever a program is going to be involved in the checkout and deployment of classified spacecraft, the handling and transmission of classified data will be encountered. Recognizing this fact, it should be obvious that TEMPEST design and test requirements will be imposed on all elements of the program (i.e., Tug, Orbiter, spacecraft, checkout/processing facilities and control stations). Imposition of these requirements will have a major impact on both design and processing activities. Therefore, subsequent paragraphs will endeavor to highlight some of the anticipated design and processing problems as well as provide certain philosophies that could lessen the overall impact on the Tug program.

The first thought that comes to mind with implementation of TEMPEST design and test requirements is the requirements imposed by such specifications as MIL-STD-461, MIL-STD 1541, AFNAG-5A and 9A, and NASCEM 5100. However, it must also be kept in mind that these specifications are prepared for general/overall application to EMC and TEMPEST techniques. Therefore, a specific program application assessment should be accomplished to define appropriate requirements. Another consideration that should be addressed is the elimination of all classified data activities from the Tug system and assigment of all classified data handling to an Orbiter/spacecraft/control station with power and grounding isolation maintained between the Tug and the spacecraft. Such decisions and extensive study will be required and should be started as early as possible.

4.3.1 Tug TEMPEST Design Requirements - In the event that the Tug system is required to handle classified data, the following paragraphs identify some of the basic design requirements that will have to be implemented. However, it should be recognized that the following recommendations are only preliminary and will require further study and are included here to highlight the extent of the impact on design.

The general EMC requirements for space equipment and subsystems are specified in the Space System Specification MIL-STD-1541 (USAF). In addition to these EMC requirements, TEMPEST-impacted circuits and equipment must be designed to pass the test requirements of NACSEM 5100. These test requirements pertain to the detection and identification of any element of the normal signal as differentiated from the ambient EMI phenomena that are not associated with the intentionally generated operational signals. The TEMPEST test involves the detection of signals conveying plain text information or commands (entering encoder equipment, or output of decoding equipment) identified in the specification as "Red," and signals conveying encoded information or control signals which would not divulge classified compromising information identified as "Black."

To protect the system, at no time will the same message sent on the uplink to the spacecraft be retransmitted on the dowlink from the spacecraft or between elements of the STS. Also, at no time will the plain text of the downlink message be retransmitted by the associated ground control station.

Design guidelines for circuits and equipment requiring TEMPEST protection will be as follows:

1) Of first importance is the requirement to provide balanced circuitry for all signal lines identified as "Red" interfacing the GFP equipment. Forward and return current of these circuits and the conductors adjacent to each other must be balanced either by twisted-pair shielded cable or by selection of parallel stacked ribbon pairs if flat ribbon cable are used. These circuits must be carefully routed in the equipment box during packaging to prevent common mode pickup in the black box that could be radiated via the external wiring or cabling.

2) To determine the requirement for isolation and shielding of single wire or unbalanced circuits carrying signals containing "Red" information the following should be used:

   a) Determine the frequency content and amplitudes of the signal wave shape.

   b) Compare the amplitudes determined in item a) with the applicable limits of NACSEM 5100 modified by AFNAG-9A. This will provide a worse case value for the required attenuation to be accomplished by shielding, isolation circuitry, or spacing and filtering.

   c) Determine the loop impedence of the circuits involved. If the loop circuit impedence is low (less than 500 ohms), current should be the predominant factor to be considered. If the loop circuit impedence exceeds 1000 ohms, voltage should be considered the predominant factor in arriving at the best method to be used to provide the desired attenuation.

   d) Evaluate the electromagnetic coupling effect of the "Red" signal lines on adjacent circuits in cable bundles to determine the need for isolation from circuits that could cause identifiable elements of the signal to be conducted or radiated in undesirable areas.

3) Grounding is an important factor in providing effective control of signal currents, shielding, and filtering, because shields and filters are used in the "Red-Black" concept to contain signal elements. Ground currents must be controlled to minimize structure currents and limit structure loop currents to controlled areas. To prevent excessive voltage drops across elements of the structure, bonding resistance for structures carrying shielding or filter currents must meet the grounding requirements of MIL-B-587B. Due to the high rate of plain text (Red) signals, the method of circuit grounding is important.

4) Shielding and electronic equipment enclosure must be considered for black boxes containing circuitry either generating or processing plain text signals identified as "Red."

4.3.2 Processing Facilities and Control Station TEMPEST Requirements - TEMPEST requirements will also be imposed on the design of the processing facilities and various element ground control station. These design requirements are obtained from NAG-5/TSEC and generally are as follows:

1) Provide at least one overall nonferrous shield on all "Red" signal, clock, and control lines that carry low-level signals.

2) There should be at least one overall nonferrous shield on all black signal, clock, and control cables from the crypto-equipment to the "Black" internal distribution junction fixture.

3) Clock lines to "Black" and "Red" equipment shall have isolation devices with the isolator arranged so that a separate isolation device is provided for each "Red" equipment timing line.

4) "Red" and "Black" power and ground feeder distribution shall be separated by a minimum of 2 in. (5.1 cm). Where crossover is necessary it shall be at approximately 90 degrees (1.5 rad) with a minimum of 1-in. (2.5 cm) spacing.

5) All nonferrous shields should be terminated in the controlled access or limited access areas.

6) All lines carrying high-level "Red" signals should be enclosed in a ferrous shield.

7) The power distribution system should be enclosed in metal (conduit or ducts and junction boxes).

8) "Red" lines outside the limited-access area and inside the controlled access area should be enclosed in a separate ferrous shielded distribution system.

9) Filtered "Red" power lines must be separated from all other distribution facilities.

10) All ground lines from the "Red" frames or equipment cases shall be continuous and routed to a separate "Red" ground through a ferrous distribution system that is separated from all other distribution systems.

11) All ground lines from the "Black" frames and equipment should be routed to a "Black" ground point through a ferrous distribution system that is separate from all other distribution systems. More than one "Black" ground line may be placed in the same "Black" conduit or duct.

12) When the end instrument or crypto-equipment has common internal grounds, separate grounds shall be maintained outside the instrument or equipment.

13) All unused spare conductors shall be grounded to the signal ground of the appropriate "Red" or "Black" frame or ground point.

14) Cord patch panels, if used, shall be arranged to prevent any possible crosspatching between "Red" and "Black" panels.

15) All "Red" high-level terminal equipment shall be kept at least 3 ft (.914 m) from crypto-equipment and "Black" equipment.

16) All "Red" low level terminal equipment shall be separated at least 2 in. (5.1 cm) from "Black" equipment.

17) All control units, dc-line isolators, repeaters (relays or amplifiers), and test equipment associated with "Black" patch panels or lines leaving the limited or controlled access area shall be separated at least 3 ft (.914 m) from any "Red" processing equipment.

18) All cryptographic and "Red" low-level terminal equipment shall be separated from nonassociated wirelines, conductors, pipes, airconditioning ducts, etc, by a minimum distance of 2 in. (5.1 cm).

19) Ground wires shall be continuous, unbroken, green-wire from the case of the technical power panel to the case of each piece of equipment.

4.3.3 TEMPEST Test Requirements - TEMPEST specifications require that the test area and test setup be certified by the responsible test agency. Consideration, therefore, must be given to development or selection of an adequately shielded area and the development or selection of approved test equipment.

The area for test must be a secure area and provide shielding adequate to reduce ambient extraneous signal levels at least six decibels below the limits of NACSEM 5100 modified by AFNAG-9A. These limits indicate the need for a solid screen room with walls that include ferrous metal to altenuate magnetic fields from 100 H_z to 10 GH_z.

It should be obvious that the above requirements establish only the general ground work for satisfying Tug TEMPEST requirement and that early implementation of a study to finalize these requirements is of paramount importance.

5.0 Acquisition Design/Development Recommendation

Paragraphs 3.0 and 4.0 have discussed many required design changes and recommendations that should be accomplished to preclude problems that could occur during the operatonal phase of the Tug program. The following paragraphs summarize these recommendations and provide an index for locating the discussion related to design changes associated with the various program elements.

5.1 Tug Design Change Summary

The following is a listing of the Tug design impact items:

1) Modification to Tug attachment points to facilitate Tug handling (para 3.1.1.1).

2) C&W monitoring and functional reaction related to safing activities (para 3.1.1.2).

3) Helium venting of the Tug/payload through Orbiter overboard dumps (para 3.1.1.3).

4) Tug structures design impact related to cleaning capabilities (para 3.1.1.4).

5) Tug/payload mating to Orbiter access provisions (para 3.1.1.5).

6) Propellant and pressurant loading provisions (para 3.1.1.6).

7) Tug OFI requirements (para 3.4.1.1.).

8) Transportation data/instrumentation requirements (para 3.4.1.2).

9) Inadequate access to LH_2 horizontal dump valve and LH_2 fill, drain, and prevalves (para 3.10.1.1).

10) Inadequate access for removal of APS hydrazine spheres (para 3.10.1.2).

11) Inadequate access for removal of LO_2 capacitive mass probe and level sensors (para 3.10.1.3).

12) Maintainability design considerations (para 3.10.3).

13) Modular design concept (para 4.2.2).

14) TEMPEST design requirements (para 4.3.1).

15) TEMPEST test requirements (para 4.3.3).

5.2 Orbiter Design Change Summary

The following is a listing of the Orbiter design impact items:

1) C&W monitoring and functional reaction capabilities related to safing activities (para 3.1.2.1).

2) Helium venting of Tug/payload through one of the Orbiter T-0 launch umbilicals (para 3.1.2.2).

3) Tug/payload mating to Orbiter access provisions (para 3.1.2.3).

4) Propellant and pressurant loading provisions (para 3.1.2.4).

5.3 Facility, GSE, and TSE Design Summary

The following is a listing of the facilities, GSE, and TSE design impact items:

1) Spacecraft handling equipment and work stands (para 3.2.3.1).

2) Spacecraft simulator requirements (para 3.2.3.2).

3) Ground checkout RF requirements to support Tug/payload processing (para 3.2.3.3).

4) APS servicing unit requirements (para 3.2.3.4).

5) Propellant and pressurant loading provisions (para 3.2.4.1.).

6) Multi-use cargo canister (para 3.3.3.1).

7) Facility/GSE safety design requirements (para 3.6.3).

IV. SUPPORTING RESEARCH AND TECHNOLOGY

A. APPROACH

Our study team carefully reviewed the Supporting Research and Technology (SRT) programs that were developed by the four Space Tug Systems Study contractors and we have identified herein the tasks or parts of tasks that are directly applicable to the reusable Tug ground operations. Pertinent data from these tasks would provide a comprehensive set of SRT data for the ground operations program. The major source of ground operations data will be from development and qualification tests and factory acceptance tests.

It was evident from this SRT review that data needed for ground operations are a small part of the design or fabrication data that are the major purpose of most of the tasks. As a result, the SRT cost to obtain the needed data is only a fraction of what would be required if the hardware had to be furnished for only ground operations SRT. In addition, many of the tasks should be redefined based on the then current baseline configuration of the Tug, and in some cases the overlap between task definition by different contractors. It may not be cost effective to contract for revised SRT tasks that only support ground operations. Therefore, the SRT task descriptions are limited to an abstract of the task for ground operations and reference to the complete task description.

Costs shown in Section B are estimates for each task as contained in the Space Tug Systems Study, selected option data dump reports. The summary schedules shown in Section C are based on the data dump reports but have been revised as necessary to assure SRT completion by the anticipated Authority to Proceed (ATP) for the Tug DDT&E program.

Since MSFC is currently supporting a program that leads to development of a main engine specifically for the Tug, no applicable SRT has been identified during this study.

B. GROUND OPERATIONS SRT SUMMARY

A summary of the SRT programs that were developed during the four Tug systems studies that would provide data needed for the ground operations program is presented in Table IV-1. The SRT tasks, the estimated task cost and schedule span in months, and the type of ground operations data that would be generated, is summarized by contractor. If these tasks are consolidated to eliminate duplication and revised to reflect Tug baseline requirements when implemented, they will include the comprehensive SRT program needed to minimize ground operations program risk before DDT&E ATP.

Table IV-1 Summary of Tug SRT Applicable to Ground Operations

NO.	TASK	EST. COST $K	SCHED SPAN, months	GROUND OPERATIONS OUTPUT
	*MMC - SEE VOL 5, APPENDIX A.			
1.	(P-12) Hydrazine Thruster Life and Reuse Demonstration Program	400	12	Investigates ACPS engine refurbishment and life-including catalyst.
2.	(P-13) N_2H_4 Propellant Compatibility and Corrosion (ACPS)	132	15	Investigates ACPS component N_2H_2 corrosion detection, evaluation and cleaning.
3.	(P-14) Evaluation of Inspection, Cleaning and Maintenance Procedures for ACPS Propellant Management Device (PMD)	50	8	Establishes ACPS PMD procedures for inspection, cleaning and maintenance.
4.	(S-5) Composite Honeycomb Assurance	150	14	Identifies methods for nondestructive test and evaluation.
5.	(S-10) Crack Detection Sensitivities for Thin Gage Tank Liners and Joints	105	18	Determines detection sensitivity and reliability for methods of nondestructive evaluation of thin gage tank liners and joints.
6.	(S-14) Composite Overwrapped Tank Assurance	158	11	Identifies methods for nondestructive detection, characterization and evaluation of composite overwrapped tanks.
7.	(M-2) Composite Structure Development	86	18	Establishes techniques to inspect, test, evaluate and repair composite structure.
8.	(T-1) Reusability of Multi-Layer Insulation (MLI)	323	18	Establishes number of use cycles for MLI before refurbishment.
9.	(T-2) Reusability of Tug Coatings	333	18	Determine frequency and develops techniques for refurbishment of thermal coatings.
	* GDC - SEE VOL 5, BOOK 2			
10.	N_2H_4 ACPS Catalyst Bed Life	250	12	Determines frequency of ACPS catalyst bed replacement.
11.	Reliable Instrumentation to Support Maintenance	200	24	Provides for dependable self-checking to minimize diagnostic test time.
12.	Redundant Components Checkout Techniques	200	24	Identifies techniques for evaluating redundant components.
13.	Tankage High Confidence Assessment Techniques	300	18	Investigates techniques for evaluating tank condition.
14.	Meteroid Impact Effects on Composite Materials and Pressurized Tankage	100	12	Establishes damage criteria constraints for meteroid cratering and spallation.
15.	Insulation Purge Gas Dissipation, Conductivity Testing and Damage Assessment Techniques	300	24	Identifies techniques for insulation damage assessment.
16.	Composite Material Minimum Gage Determination	250	18	Develops thin gage composite material handling techniques.
	* MDAC - SEE VOL. 8, BOOK 2			
17.	Develop Potential Hazard/Failure Detection Techniques	750	18	Provides a prototype damage control system.
18.	Star Tracker Self-Check and Calibration	3,000	18	Extends technology to permit onboard calibration.
19.	Inertial Measurement Unit Self Calibration	2,000	18	Provides for full onboard calibration.
	* GAC - SEE VOL. 8, PART II			
20.	Advanced IMU for Space Application	500	18	Develops software and procedures for calibration of gyros on the launch pad.

* Document referenced is from the contractor's Space Tug Systems Study selected option data dump.

C. GROUND OPERATIONS SRT SCHEDULES

The time phasing of the SRT program relative to Phase B and the DDT&E ATP for the Tug program are shown in Figure IV-1. This time phasing is controlled by program definition requirements during Phase B and by the requirement to complete SRT by DDT&E ATP.

D. SRT ABSTRACT FOR GROUND OPERATIONS

Abstracts of those portions of the SRT tasks described in the Space Tug System Study, selected option data dump that are applicable to ground operations are presented in the following paragraphs. Since no description of the GDC tasks included in Sections B and C are provided in the documentation available to Martin Marietta, only a detail reference to the available data is provided.

1.0 Hydrazine Thruster Life and Reuse Demonstration Program

This task is identified as SRT No. P-12 and described in Vol 5, Appendix A, on pages A-39 and A-40 of the Martin Marietta data dump. It provides for an APS engine test program to investigate potential problem areas related to long life and refurbishment, including catalyst bed refurbishment. This task would provide data for projecting both refurbishment and replacement requirements for the ground operations program.

2.0 N_2H_4 Propellant Compatibility and Corrosion

This task is identified as SRT No. P-13 and described in Vol 5, Appendix A, on pages A-41 through A-43 of the Martin Marietta data dump.

Data is available on short term compatibility of hydrazine with a number of APS propulsion materials, but data should be developed by long term compatibility testing based on relatively long duration missions and reuse. The combined synergistic effect of air contamination on structural components and a variety of composite materials when wet with propellant or exposed to propellant vapors should be determined.

Ground operations data would be developed as follows:

1) Special cleaning procedures for tankage materials and joints;

2) Methods of detecting deterioration of surface finish, strength, and flexibility; and methods of decontamination of exterior surfaces of test articles.

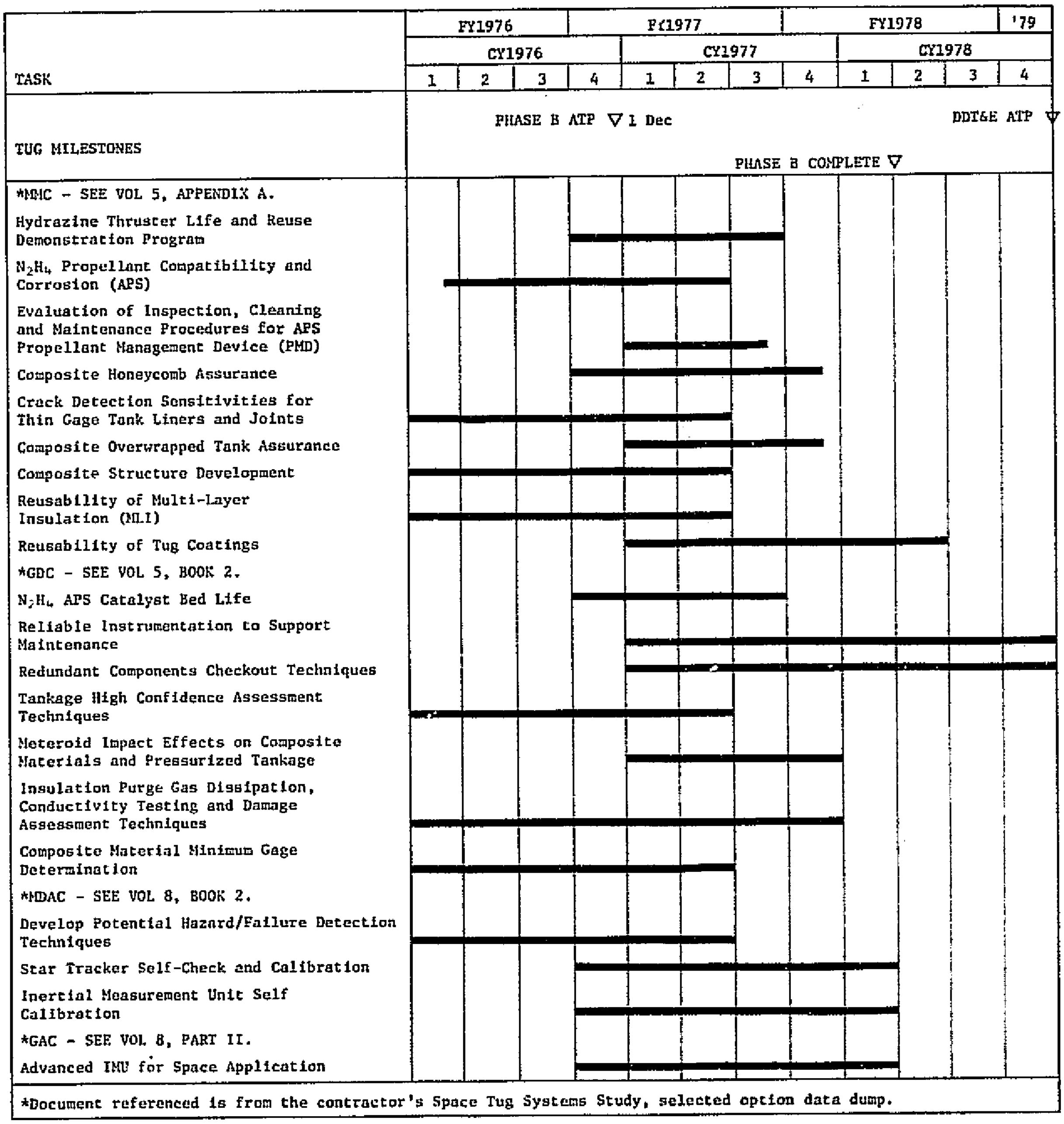


Figure IV-1
Summary Schedule for Tug SRT Applicable to Ground Operations

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3.0 Evaluation of Inspection, cleaning and Maintenance Procedures for Tug APS Propellant Management Device

This task is identified as SRT No. P-14 and described in Vol 5, Appendix A, on pages A-44 and A-45 of the Martin Marietta data dump.

A fine mesh screen is the propellant management device (PMD) that is investigated in this task. While the current baseline Tug configuration does not use this type of APS PMD, it is being used in the Orbiter. Since MSFC expects to reevaluate the PMD baseline in the future based on Orbiter experience, we have retained the task.

The reusable Tug requirements emphasize need for all subsystems to be easily inspected and as maintenance free as possible. Since the screen-type PMD is an integral part of the APS tank, it should be capable of remote inspection and cleaning.

The approach would be to conduct a series of ground tests using a representative APS tank and PMD. Flow tests would be developed to establish the condition of the screen, and procedures established to unplug the screen. The objective would be to establish inspection, maintenance, and cleaning procedures for the APS propellant management device.

The task cost is based on the free use of a representative APS tank and screen.

4.0 Composite Honeycomb Assurance

This task is identified as SRT No. S-5 and described in Vol 5, Appendix A, on pages A-93 and A-94 of the Martin Marietta data dump.

The objective of this task, that is of ground operations interest, is to identify methods for nondestructive detection and evaluation of the structural integrity of composite honeycomb structures. To accomplish this component elements containing typical fabrication anomalies would be tested by nondestructive methods and the results evaluated.

5.0 Crack Detection Sensitivities for Thin Gage Tank Liners and Joints

This task is identified as SRT No. S-10 and described in Vol 5, Appendix A, on pages A-101 and A-102 of the Martin Marietta data dump.

It includes the fabrication and nondestructive test and evaluation of subscale overwrapped tanks containing known thin gage tank liner and joint cracks. The objective of determining detection sensitivity and reliability of several methods of nondestructive testing is important to ground operations.

6.0 Composite Overwrapped Tank Assurance

This task is identified as SRT No. S-14 and described in Vol 5, Appendix A, on page A-106 of the Martin Marietta data dump.

This task requires the fabrication of overwrapped tanks with anomalies such as unbonds, low strength, and broken fibers. These tanks are tested to establish sensitivities of nondestructive evaluation methods. The objective is to identify methods of nondestructive detection, characterization, and evaluation of composite overwrapped tank structural integrity. This data is needed for ground operations as well as for factory integrity testing.

7.0 Composite Structure Development

This task is identified as SRT No. M-2 and described in Vol 5, Appendix A, on pages A-110 and A-111 of the Martin Marietta data dump.

This is basically a task to develop manufacturing techniques for composite structure that would be in support of the concurrent engineering SRT tasks. However, the effort associated with modification and repair should establish techniques to inspect, test, evaluate, and repair composite structure. This data is needed for ground operations.

8.0 Reusability of Multi-Layer Insulation (MLI)

This task is identified as SRT No. T-1 and described in Vol 5, Appendix A, page A-116 of the Martin Marietta data dump.

In addition to providing data to suppor the selection of the best MLI material, this task includes use cycle tests under the most injurious Tug environments of a large MLI blanket and an MLI wrapped APS propellant line. This should establish the number of use cycles of MLI before refurbishment for ground operations planning.

9.0 Reusability of Tug Coatings

This task is identified as SRT No. T-2 and described in Vol 5, Appendix A, on page A-117 of the Martin Marietta data dump. This task is an investigation of thermal coatings. In addition to providing data to support the selection of the best coating material,

this task includes life cycle tests under simulated Tug environments that should establish for ground operations the frequency and techniques for refurbishing thermal coatings.

10.0 GDC SRT TAsks

SRT tasks No. 10 through 16 are identified by General Dynamics. We cannot prepare a ground operations abstract for these tasks because the only documentation available to us is that in Vol 5, Book 2, Section 5.8, on pages 284 through 286 of their data dump. The ground operations output indicated in Table IV-1 was derived from General Dynamics' Figure 5.8-1 on page 285.

11.0 Develop Potential Hazard/Failure Detection Techniques

This task is described in Vol 8, Book 2, Section 10, on pages 10-1 through 10-5 of the McDonnell Douglas data dump.

The task is based on recognition that current technology is inadequate to provide the basis for design of a permanently installed monitoring system to give early warning of tank and general plumbing leaks, or precursor damage notes to allow effective remedial action to be taken. The objective is to develop and test a prototype continuous monitoring system that would monitor potential failure modes in space and also function as part of the ground checkout system before launch. Acoustic detection techniques appear promising for tanks and a tape detection technique for plumbing, valves, etc.

12.0 Star Tracker Self-Check and Calibration

This task is described in Vol 8, Book 2, Section 10, on pages 10-10 and 10-11 of the McDonnell Douglas data dump. The task is concerned with the need to perform onboard ground checks and calibration of star trackers without removing the equipment from the Tug. Existing technology, based on using a light emitting diode to simulate the star signal, should be extended to permit onboard calibration.

13.0 Inertial Measurement Unit (IMU) Self-Calibration

This task is described in Vol 8, Book 2, Section 10, on pages 10-11 and 10-12 of the McDonnell Douglas data dump. As a result of recent development an existing IMU configuration includes a single calibration gimbal about the system roll axis, and an additional step-index mechanism around a selected set of instruments. These calibration mechanisms can be locked in a known reference position before flight. The object of this task would be to extend this concept to three gimbals to provide a cost effective means of achieving full onboard IMU calibration, thus facilitating ground operations.

14.0 Advanced IMU for Space Application

This task is described in Vol 8, Part II, Section 8.10 on pages II-8.10-9 and II-8.10-10 of the General Dynamics' data dump.

The task is based on developing an advanced, low-weight IMU from the unit that is currently being developed under Air Force contract primarily for aircraft applications. To facilitate ground operations, the technical approach includes development of software and procedures for calibration of gyros on the launch pad.

V. RECOMMENDED ADDITIONAL EFFORT

In the performance of any study, certain items that require additional analysis beyond the scope of the original effort become evident. These additional studies arise as a result of new information that comes to light during the study, or as a result of ground rule/assumption changes.

These items have been documented incrementally as they surface in the course of our study. Many were considered to be those activities that will be performed by either the Tug contractor or the NASA Tug project in the normal development of the Tug. Because it serves no useful purpose to list these normal activities here, they were dropped from further discussion. Other items more appropriately fall within the definition of SRT and are treated in Chapter IV. The remaining items were then screened for those that require attention within the next few years or those that have significant front-end impact on the Tug program. This screening yielded the thirteen items defined in Table V-1.

Table V-1 Summary Cost and Schedule for Recommended Additional Effort

Task	Estimated Cost ($K)	1975 / FY 1976 / FY 1977 / FY 1978 (CY 1975, CY 1976, CY 1977, CY 1978; 1 2 3 4)
TUG MILESTONES	.	Phase B ATP; Phase B Complete; DDT&E ATP
Tug Hydrazine Auxiliary Propulsion System Checkout	109.0	
Tug Spacecraft Ground Operations Integration Study	312.0	
LRU Contingency Changeout Impact Study	156.0	
Determine Optimum Tug Leak Check Techniques	156.0	
Integrated Transportation Study for Payload Modules	81.0	
LRU Replacement vs In-Place and Off-Line Repair	106.0	
IUS/Tug Station Set Requirements	153.0	
Classified Payload Tempest Impact Study	154.4	
Tug Input to IUS User's Guide	81.0	
Tug User's Guide Preparation	245.5	
Man-Computer Systems Applicable to Fleet Utilization Management	207.7	
Fleet Utilization Study for NASA IUS	117.5	
Provide Tug Data to Support the DOD STS Ground Support Systems Definition Study	168.3	
Total	2,047.4	

A. TASK 12, ITEM 1

1.0 Title -- Tug Hydrazine Auxiliary Propulsion System Checkout

2.0 Purpose

Study the Auxiliary Propulsion system (APS) requirements for checkout when the system is reused for approximately 20 missions. This includes impact on the airborne design as well as the ground system and facility requirements.

3.0 Objectives

The primary objectives of this study are:

1) Establish decontamination requirements for system checkout as well as hardware replacement. (Use the results from the SRT task described in Part IV, paragraph D.2.0 above.)

2) Establish impact on the airborne design for decontamination when hardware replacement is required. (Ports between series thrust chamber valves for diameter, purge, etc)

3) Establish impact on ground system and facility for checkout and hardware replacement. (Example: If the system is not decontaminated safety may require a special facility location or restrict access.)

4) Establish checkout requirements to guarantee system integrity for operation, and fail operate/fail safe criteria.

5) Establish APS time lines for checkout, hardware replacements, etc.

6) Establish catalyst bed cooldown characteristics and compare to Shuttle time lines of deorbit through landing for compatibility. (A warm catalyst bed can be permanently damaged if exposed to air-CO_2.)

7) Establish critical components in hydrazine thruster for refurbishment and rebuild.

4.0 Schedule

This 10-month study should start in April 1977 to provide inputs on the airborne design, AGE design, and facility requirements.

5.0 Budget

The estimated cost of $109,000 for this study is based on 25 man-months of engineering, $104,000 total labor cost, and $5000 for 5 two-man trips.

6.0 Special Facilities

None required.

B. TASK 12, ITEM 2

1.0 Title -- Tug/Spacecraft Ground Operations Integration Study

2.0 Purpose

Study Tug/spacecraft ground operations integration to greater depth than presently planned in existing studies. This should include prelaunch, launch, and postlaunch activities applicable to Tug/spacecraft integration.

3.0 Objectives

The primary objectives of this study are as follows:

1) Analyze Tug/spacecraft mating and develop a functional flow diagram for all launch site activities from that point through launch. (Includes TPF and PCR mating of KSC and PCR mating at WTR.)

2) Perform special emphasis assessment:

   a) When and where to service spacecraft,

   b) Spacecraft contamination control,

   c) Impact of EMI/TEMPEST demonstration requirements,

   d) Spacecraft-to-Tug mating/demating function and constraints (single and multiple spacecraft),

   e) Transportation and handling requirements.

3) Contingency planning, i.e., one of multiple spacecraft fail.

4) Determine Tug/spacecraft software integration techniques.

4.0 Schedule

This 12-month study should start in August 1975 to assure adequate GFE and facility definition.

5.0 Budget

The estimated cost of $312,000 for this study is based on 72 man-months of engineering, $300,000 total labor cost, and $12,000 for 12 two-man trips.

6.0 Special Facilities

No special facilities or laboratories will be required.

C. TASK 12, ITEM 3

1.0 Title -- LRU Contingency Changeout Impact Study

2.0 Purpose

Study the capability to changeout Tug/IUS and spacecraft LRUs at the PCR or in the Orbiter payload bay. This study should be accomplished to assess not only completeness of checkout capability and access, but will determine and minimize downtime related to LRU failure/anomalies occurring late in the Tug/IUS and spacecraft processing cycle.

3.0 Objectives

The primary objectives of this study are:

1) Establish criticality of LRU failures/anomalies that could cause mission abort and provide rationale for recommended corrective action.

2) Establish and document guidelines and ground rules for accomplishment of LRU changeout at PCR or in Orbiter payload bay.

3) Assess GSE and check out software capability to perform reverification of replaced LRUs, and recommend additional portable GSE as required.

4) Provide design change impacts to enhance contingency changeout capability.

5) Prepare backout planning for LRU change out at the PCR or in the Orbiter payload bay, including functional flows, timelines, GSE, skills, and reverification requirements.

4.0 Schedule

This study should be performed early in the program to provide LRU installation design criteria, which will enable LRU contingency changeout. It is recommended that this 18-month study start in August 1975.

5.0 Budget

The estimated cost of $156,000 for this study is based on 36 man-months of engineering, $150,000 total labor cost, and $6000 for 6 two-man trips.

6.0 Special Facilities

None required.

D. TASK 12, ITEM 4

1.0 Title -- Determine Optimum Tug Leak Check Techniques

2.0 Purpose

As spacecraft missions become more sophisticated, and operate for increasingly greater periods to time, the requirements for improved performance by the Tug systems and components become tighter. One measure of performance is the ability of the fluid flow system, or individual component, to perform satisfactorily under all predicted conditions without failure, which includes without excessive leakage.

Excessive gas or propellant leaks could: (1) affect the performance of an onboard scientific experiment located near the leak exit; (2) require additional attitude control system compensation to create an abnormal increase of operating fluid consumption; (3) create a hazardous condition resulting from accumulation in the spacecraft; and (4) decrease the operating fluid's reserve to cause a system's decreased performance, or even a malfunction.

The word "excessive" is relative to the size of the system and to the quantity of the reserve operating fluids. The need for maximizing the payloads is a constant system factor. The resulting Tug propulsion system requirements demand economy of propellants and pressurizing gases. The requirement for extremely small or no leakage is becoming a prime requisite.

3.0 Objectives

The development of techniques to detect leaking fluids has been slow. The problem has been complicated by the fact that many less-than-satisfactory means of defining the leakage requirements have been attempted for the sake of reducing costs, simplifying design, procurement, and testing specifications. There are, however, several attractive techniques applicable to leak testing the Tug MPS tanks, lines, mechanical components, the APS bladder, lines and components, the fuel cell reactant system, and the propellant tank purge bag and MLI. These are:

1) Continuous mass flow;

2) Mass pressure decay/reference volume;

3) Soap solution bubble;

4) Mass spectrometer (helium sniff);

5) Acoustic (sonic detector);

6) Chemical test papers.

These techniques provide varying degrees of accuracy of leak rate: acoustic, 1 cm^3/min; soap bubble, 1 cm^3/hr; mass spectrometer, 1 cm^3/day; and chemical test papers, 1 cm^3/wk. These techniques require varying lengths of time to determine if leakage exists and what the leak rate is. Each technique requires unique equipment varying in cost and degree of skill/training required to operate. The selection of a technique could impact the Tug design timelines, turnaround costs, operational safety, facility design, and manpower requirements.

In view of Tug turnaround requirements and turnaround time effects on fleet sizing, coupled with the effects of using helium as a pressurant on Tug and spacecraft components and systems, a study should be performed to determine the optimum approach to leakage integrity verification of the Tug fluid and pressure systems. This study sho 'd consider: (1) time span of leakage determination on the Tug refurbish/checkout/turnaround cycle; (2) effects of fluids/vapor in a system during leak check, i.e., APS N_2H_4; (3) approach to leak checking and purging thin membranes such as the MLI and purge bag; (4) desirability of use of a full-time leak detection system during mission operations, i.e., chemical paper, piezo-electric devices; (5) the safety aspects of each leak detection techniques; (6) effects of leakage at sea level vs on-orbit; and (7) costs (equipment, personnel, training, etc) of various leak-check techniques considered.

The results from SRT tasks such as those described in Part IV, paragraphs D.5.0 and D.11.0 above would enhance this study.

4.0 Schedule

The selected leak detection approach could impact Tug component and systems design, refurbish/checkout facility requirements, and GSE design, and should be considered in the early phases of the Tug development program. It is estimated that a study of this nature will require a period of approximately 9 months to complete. Based on current Tug planning, the study should be started no later than July 1977.

5.0 Budget

The estimated cost of $156,000 for this study is based on 36 man-months of engineering, $150,000 total labor cost, and $6000 for 6 two-man trips.

6.0 Special Facilities/Support

No special facilities would be required. Access to NASA/contractor SRT related to this study would be required.

E. TASK 12, ITEM 5

1.0 Title -- Integrated Transportation Study for Payload Modules

2.0 Purpose

Perform an integrated analysis of all transportation requirements imposed by Tug, IUS, kick stage, and spacecraft leading to establishment of a common mode of transportation and preliminary configuration of common transportation support equipment (TSE). Many contractors, as well as NASA agencies, have performed preliminary transportation studies for Tug, IUS, and kick stage individual applications. Little has been done on the multiple configurations of spacecraft. Nothing has been done to establish commonality across all transportation requirements and to assess the capability and schedule availability of the B-747 carrier aircraft and the cargo canister concept to meet these requirements. Preliminary cost tradeoffs must be performed between individual transportation approaches for each of the payload modules and a common B-747/cargo canister approach. Additionally, a three-phase approach must be established for preliminary design of a cargo canister. Phase 1 must define a common configuration to meet the multiple requirements for air transport. Phase 2 must define the ground handling configuration of the canister. Phase 3 must marry air and ground requirements and establish feasibility and configuration of a dual use canister for air transportation and ground handling.

3.0 Objectives

The primary objectives of this study are:

1) Consolidate and review all transportation analyses available to date including External Tank movement by B-747.

2) Develop spacecraft transportation analysis as required.

3) Establish common or individual transportation approaches for the payload modules on the basis of cost tradeoffs.

4) Establish capacity of B-747 carrier aircraft to meet common transportation approach.

5) Define cargo canister configuration based on:

   a) Air transport requirements,

   b) Ground handling requirements,

   c) Dual use requirements.

6) Develop preliminary cargo canister design.

7) Define approach to other common TSE and examine use and cost saving of existing GSE.

4.0 Schedule

This 12-month study should start in April 1975 to support timely NASA transportation decisions that will be required to baseline use of the B-747 and canister. Dual use of the canister may impact facility and GSE design.

5.0 Budget

The estimated cost of $81,000 for this study is based on 18 man-months of engineering, $75,000 total labor cost, and $6000 for 6 two-man trips.

F. TASK 12, ITEM 6

1.0 Title -- LRU Replacement versus In-Place and Off-Line Repair

2.0 Purpose

This study will perform in-depth analysis of the evolving Tug configuration with emphasis on component design impact on spares cost and provisioning methods, and time/cost to repair in place or off-line versus remove and replace. Current emphasis on LRU replacement implies a volume of high cost spares on site. Although turnaround time is a major driver favoring the LRU concept, maintenance workaround has not been sufficiently investigated and cost tradeoffs have not been worked in terms of total Tug program impact.

3.0 Objectives

The objectives of this study are:

1) Establish definitive spares levels and cost information for all Tug components consistent with current baseline configuration.

2) Establish preliminary MTBF/MTBR and time to repair data. Correlate with maintainability data.

3) Perform timeline analysis and cost tradeoff between replacement and repair in place or off-line.

4) Investigate alternative maintenance processing approaches that could support repair rather than replace, consistent with timeline constraints.

5) Establish design criteria to implement/facilitate repair actions as appropriate.

4.0 Schedule

This 12-month study depends on a relatively firm baseline configuration, but should be started in the second quarter of 1976 to provide sufficient lead time to impact the design process.

5.0 Budget

The estimated cost of $106,000 for this study is based on 24 man-months of engineering, $100,000 total labor cost, and $6000 for 6 two-man trips.

6.0 Special Facilities/Support

No special facilities would be required. Access to latest baseline Tug configuration must be assured.

G. TASK 12, ITEM 7

1.0 Title -- IUS/Tug Station Set Requirements

2.0 Purpose

Define the IUS/Tug requirements for incorporation into the station sets.

3.0 Objectives

The primary objective of this task is to define station set requirements for IUS/Tug. Requirements are to be prepared using the results of NASA/DOD studies. The total station set requirements are to be analyzed to determine which station set(s) require IUS/Tug inputs. Once the number of station sets have been determined, all IUS/Tug systems, safety, and service requirements will be determined. These requirements will then be presented in the station set format.

4.0 Schedule

This 6-month study should start no later than March 1975, concurrent with the DOD/STS Ground Support Systems Definition Study, to impose proper IUS/Tug station set requirements and thus reduce program impact and schedule delays during acquisition and activation.

5.0 Budget

The estimated cost of $153,000 for this study is based on 36 man-months of engineering, $150,000 total labor cost, and $3000 for 3 two-man trips.

6.0 Special Facilities/Support

No special facilities or laboratories would be required. Close coordination between the DOD/STS Ground Support Systems Definition Study and this study would be required.

H. TASK 12, ITEM 8

1.0 Title--Classified Payload TEMPEST Impact Study

2.0 Purpose

Evaluate and optimize TEMPEST test and design requirements related to the Tug/IUS, spacecraft, and the Orbiter/Shuttle interface. The study should be conducted to ensure appropriate design considerations be given to each element of Tug/IUS and spacecraft programs to preclude the necessity of major modifications or extensive TEMPEST testing during Tug/IUS processing and mate/demating operations.

3.0 Objectives

The primary objectives of this study are:

1) Review preliminary design of program elements to ensure proper implementation of TEMPEST criteria, and where possible provide design recommendations that will optimize data formats and handling to reduce test requirements.

2) Review facility and GSE items to assure compliance with TEMPEST requirements and perform design optimization to minimize TEMPEST test requirements.

3) Review ground operations to assure proper implementation of TEMPEST test requirements and establish proper handling procedures and security safeguards.

4) Provide criteria input for Tug/IUS user's guide to simplify interface testing and optimize data handling requirements.

5) Provide an EMC/TEMPEST control document for regulation and control of TEMPEST design and test requirements.

These activities should be accomplished as early as possible to impose proper data formats/handling and design requirements in the early design phase of the program elements to reduce program impact and schedule delays during acquisition and activation.

4.0 Schedule

This 12-month study should start in the second quarter of 1975 to be of benefit during Tug/IUS and spacecraft design.

5.0 Budget

The estimated cost of $154,400 for this study is based on 36 man-months of engineering, $150,000 total labor cost, and $4400 for 4 two-man trips.

6.0 Special Facilities

No special facilities or laboratories will be required beyond normal industrial security areas and depositories, and access to Tug/IUS and spacecraft baseline and/or preliminary design documentation. Engineers must have appropriate security clearances.

I. TASK 12, ITEM 9

1.0 Title--Tug Input to IUS User's Guide

2.0 Purpose

Input data should be developed for use by DOD in preparing the IUS User's Guide to assure that the initial design of spacecraft planned for both IUS and Tug delivery will have flexibility, and that adequate accommodations are provided on spacecraft that are to be retrieved by the Tug.

3.0 Objective and Approach

The objective of Tug input to the IUS User's Guide should be to provide the following data for IUS payload users that plan to use the Tug for spacecraft retrieval or for delivery of subsequent spacecraft of the same design after the Tug is available:

1) Tug-peculiar requirements that are to become compatible with the standardized IUS interfaces and documentation;

2) Identification of those Tug-peculiar elements requiring agreements between participating agencies.

We recommend the following approach to the preparation of this input data:

1) Establish a logic diagram and schedule for the input data preparation that is compatible with the plan for the preparation of the IUS User's Guide.

2) Prepare and obtain NASA approval of a definitive outline that establishes format and content, and identify data required from NASA agencies and DOD commands.

3) Conduct a review of applicable documents with particular emphasis on payloads to be delivered by the IUS and later delivered/retrieved by the Tug.

4) Prepare the input data so that the additional compliance requirements for IUS payloads that will later be Tug payloads are minimized and the Tug-peculiar requirements of JSC 07700, Volume XIV-Space Shuttle System Payload Accommodations are met.

5) Identify those areas where physical, functional and/or operational constraints imposed by IUS payloads later becoming Tug payloads are incompatible and should be reviewed by NASA/DOD for possible accommodation changes and subsequently incorporated in the IUS User's Guide.

4.0 Schedule

This 6-month study should start concurrent with the IUS Validation Phase ATP that we currently project as October 1975 to provide data for incorporation in the IUS User's Guide by the April 1976 CDR.

5.0 Budget

The estimated cost of $81,000 for this study is based on 18 man-months of engineering, $75,000 total labor cost, and $6000 for 6 two-man trips.

J. TASK 12, ITEM 10

1.0 Title--Tug User's Guide Preparation

2.0 Purpose

The Tug User's Guide should be developed for use as a management tool for the Tug/spacecraft integration agency.

3.0 Objective and Approach

The objective of the Tug User's Guide should be to provide the following data for Tug payload users:

1) Standardized requirements for interfaces and document reduction;

2) Services and facility accommodations provided by the Tug project;

3) Roles and responsibilities for processing the Tug and its payload at the launch site;

4) Methodology, techniques, and responsibility assignments for analytical analysis of payload effects;

5) Identification of those elements requiring agreements between participating agencies.

We recommend the following approach to the Tug User's Guide preparation:

1) Establish a logic diagram and schedule for the document preparation;

2) Prepare and obtain NASA approval of a definitive outline that establishes format and content, and identify data required from NASA agencies and DOD commands;

3) Conduct a review of applicable documents with particular emphasis on payloads defined to be delivered/retrieved by the Tug;

4) Prepare the guide so that Tug user flexibility is maximized and the requirements of JSC 07700, Volume XIV Space Shuttle System Payload Accommodations are met;

5) Identify those areas where the physical, functional, and/or operational constraints imposed by the Space Shuttle system and the Tug are incompatible with Tug payload requirements and should be reviewed by NASA for possible accommodation changes and subsequent incorporation in the Tug User's Guide.

4.0 Schedule

This 15-month study should start in April 1976, immediately following the study to provide Tug input to the IUS User's guide described above. Preparation of the Tug User's Guide at this time will assure comprehensive Tug/spacecraft interface and integration requirements prior to Tug Phase B complete for use during both spacecraft design and the preparation of the final Tug Phase B definition documentation.

5.0 Budget

The estimated cost of $245,500 for this study is based on 57 man-months of engineering, $237,500 total labor cost, and $8,000 for 8 two-man trips.

6.0 Special Facilities/Support

No special facilities are required. Pertinent Tug DDT&E phase data and meeting participation, as well as other pertinent agency data, will be required.

K. TASK 12, ITEM 11

1.0 Title--Man-Computer Systems Applicable to Fleet Utilization Management

2.0 Purpose

The purpose of this study is to adapt state-of-the-art scheduling techniques to the functional requirements that MSFC is currently generating for the Payload/Spacelab Utilization Planning System. These functional requirements are also generally applicable to the Tug Fleet Utilization Planning System discussed in Part III Subplan B above, as well as the STS Fleet Management System, the Launch Processing System, and the Vehicle Management and Mission Planning System.

3.0 Background and Objective

Computer algorithms capable of solving all planning, scheduling, and resource allocation functions needed in the Tug Fleet Utilization Planning System are not available. However, combinations of computer algorithms and man's problem solving capabilities can meet the function requirements. Previous man-computer planning systems have been deficient because of design tendencies that emphasized algorithm sophistication. The systems designed with this emphasis have often been difficult to use, and have included such high-level functions that their development times have been excessive. When the test phases for such systems were finally reached, it was often discovered that the systems could not perform the common low-level functions effectively. New ideas for planning systems have been generated that attempt to use human talents and expertise wisely in an integrated man-computer system involving classical scheduling techniques. The computer functions within such a system are not only within the state of the art, but are also sufficiently common to preclude the need for expensive software development efforts that might be necessary for other systems designs. These ideas should be applied to the functional requirements before system implementations are begun.

The objective of this study would be to determine how the functional requirements currently being developed should be automated in terms of the roles of man versus the computer. It would include the assignment and execution of man and computer functions within proper boundaries. This study should effect substantial savings during the subsequent software development and implementation phases.

4.0 Schedule

This 12-month study should be started in the fourth quarter of 1975, following the completion of the functional requirements currently being developed under MSFC contract.

5.0 Budget

The estimated cost of \$207,675 for this study is based on 48 man-months of engineering, \$200,000 total labor cost, \$3,675 for 5 hours of computer time, and \$4000 for 4 two-man trips.

6.0 Special Facilities/Support

No special facilities would be required. The functional requirements to be used for the study would be furnished by NASA.

L. TASK 12, ITEM 12

1.0 Title--Fleet Utilization Study for NASA IUS

2.0 Purpose

Assess the total IUS, including kick stage and program payload/mission requirements to optimize hardware and software procurement and to consider significant impacts caused by perturbations to the planned DOD IUS operating plan.

3.0 Objective

The overall objective is to provide realistic IUS and kick stage sensitivity data and contingency planning for uneven launch centers, spacecraft schedule changes, hardware and software anomaly and failure impacts, and programmatic impacts, such as schedule revisions and priority payload impacts. Primary "real world" contingencies that should be considered are shown in Table V-2 with possible/potential impacts. Tradeoff studies should be performed to determine the optimum course of action. Contingency plans for flight hardware, GSE, software, and facilities should be established based on the ground operations contingency situations. The baseline flow that should be used is the one selected from those being developed in the IUS systems studies currently being conducted for the DOD.

Table V-2
Contingencies and Situations Impact Operations, Missions, and IUS Fleet Requirements

	Potential Impact									
Contingency	Repair Payload	Recycle Payload	Fly Failed Payload	Fly without Payload	Repair IUS	Fly Alternative IUS	Fly Mass Simulator	Fly Buffer Payload	Reschedule Missions	Delay Flight
Flight Hardware										
Payload No Show				X			X	X	X	X
Payload No Go	X	X	X	X			X	X	X	X
IUS No-Show						X		X	X	X
IUS No-Go					X			X	X	X
Payload to IUS Interface	X	X			X		X	X	X	X
IUS to Orbiter Interface					X		X	X	X	X
Payload-to-Payload Interface	X	X	X	X			X	X	X	X
Facilities										
Stackup								X	X	X
Failure								X	X	X
GSE										
Late Delivery								X	X	X
Failure								X	X	X
Software										
Late Delivery								X	X	X
Failure								X	X	X
Programmatics										
Schedule Changes				X			X	X	X	X
Priority Payload									X	X
Uneven Launch Centers									X	X
Safety									X	X
Safety		X								X
Manpower								X	X	X

A system should be developed for tracking and controlling the resources and activities so that management may take early corrective action to preclude serious schedule and/or cost impacts. Current airline-type fleet management techniques, data management approaches, configuration control systems, and performance measuring systems should be evaluated and an optimized overall fleet/operations management scheme developed.

From the data developed in this study a plan should be prepared that would present the overall organization and program planning, and control documentation recommendations including recommended management tools such as alerts and techniques for developing work-around solutions to problems occurring during the ground operations phase of the IUS program. This plan should also include the basic contingency plans and work-arounds for those broad major contingencies shown in Table V-2.

4.0 Schedule

To support IUS procurement and operations planning, this study should start no later than the 4th quarter of 1975. It is estimated that this study would require approximately nine months to complete.

5.0 Budget

The estimated cost of $117,500 for this study is based on 27 man-months of engineering, $112,500 total labor cost, and $5000 for 5 two-man trips.

6.0 Special Facilities/Support

No special facilities would be required. Pertinent IUS validation phase data and meeting participation, as well as other pertinent agency data, would be required.

M. TASK 12, ITEM 13

1.0 Title--Provide Tug Data to Support the DOD STS Ground Support Systems Definition Study

2.0 Purpose

Provide Tug ground operations data, requirements, and planning to support the DOD STS Ground Support Systems Definition Study to assure overall Tug ground operations planning compatibility.

3.0 Objective

The primary objectives of this activity are to:

1) Provide Tug ground operations planning, timelines, and manpower support requirements to the DOD Ground Support Systems Definition Study as required.

2) Update Tug ground operations planning data to the DOD Ground Support Systems Definition Study as Tug changes are made.

3) Evaluate and assess impact of DOD STS planning on Tug ground operations.

4) Coordinate DOD STS ground support Tug planning impacting Tug operations with NASA to develop positions/work-arounds acceptable to NASA and DOD. Provide coordinated impacts to the DOD Ground Support Systems Definition Study.

5) Maintain and provide a Tug ground operations functional flow diagram and accompanying GSE and facility data sheets reflecting impacts of the coordinated (NASA and DOD) overall STS planning for Tug.

6) Maintain and provide Tug software and data requirements information as changes occur.

7) Provide and update Tug contingency planning and alternative landing site operational requirements.

8) Perform liaison between the DOD STS Ground Support System Definition Study Team and NASA to provide NASA with current DOD STS Tug planning data for impact evaluation, and provide NASA planning to the DOD study team.

4.0 Schedule

This activity should start simultaneously with the start of the DOD STS Ground Support Systems Definition Study currently scheduled to start March 1, 1975 and continue through September 30, 1976. The planning phase of the DOD study runs from March 1, 1975 through December 1976.

5.0 Budget

The estimated cost of $168,300 for this study is based on 38 man-months of engineering, $158,300 total labor cost, and $10,000 for 20 one-man trips.

6.0 Special Facilities/Support

No special facilities would be required. Pertinent DOD STS Ground Support Systems Definition Study data and meeting participation, as well as other pertinent agency data, will be required.

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